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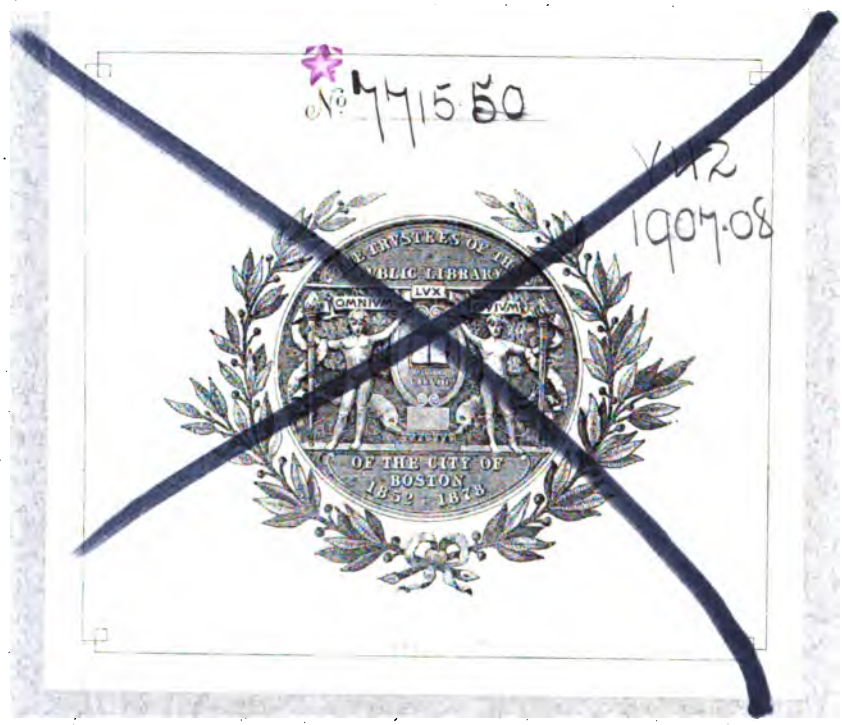
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JOURNAL OF ANATOMY AND PHYSIOLOGY

AN ACCOUNT OF THE STRUCTURES CONCERNED IN THE PRODUCTION OF THE JUGULAR PULSE.

By ARTHUR KEITH, M.D., *Lecturer on Anatomy, London Hospital Medical College.*

A STUDY of the pulse in the jugular vein has now become established as a routine method of examining disordered hearts—an advance due to the labours of Dr James Mackenzie and of those who have adopted his method.[1] With the introduction of a new clinical method, as is also the case with a new operative procedure, certain structures and relationships assume an increased importance and require a fresh description. In this paper I propose to recast our description of the structures which seem to me to be directly concerned in the production of the venous pulse—my account having reference only to the arrangement as found in the human body. I propose to deal not only with the normal but also with the disordered heart, using for this purpose the series of specimens sent to me for examination by Dr James Mackenzie. These hearts are of special value for the purpose of study, because Dr Mackenzie had kept accurate records of their action during many years prior to the death of the patient.

The Position of the Jugular Bulb.—The right jugular bulb, from which a tracing of the venous pulse is usually taken, is situated farther from the sternal end of the clavicle than one expects. Its position is best indicated

[1] James Mackenzie, *The Study of the Pulse* (1902), and numerous papers in the *British Medical Journal* during 1905, 1906. See also Professor Wenckebach's *Arrhythmia of the Heart*, translated by Snowball, 1904, and especially this author's article in the *Archiv für Anat. und Physiol.*, 1906, p. 297; papers by Dr G. A. Gibson, *Edin. Medical Journal*, 1905, N.S. vol. xviii., p. 9; *British Medical Journal*, 1906, vol. ii. p. 1113; by Dr John Hay, *British Medical Journal*, 1905, vol. ii. p. 1034; *Lancet*, 1906, vol. i. p. 139. A full list of papers dealing with records of the jugular pulse is given by Dr John Cowan, *Practitioner*, April 1907.

by a point—*the jugular point*—on the upper border of the clavicle, 25–30 mm. from the sternal end (fig. 1). With the patient in the supine position, the jugular valves which demarcate the bulb from the rest of the vein are situated about 20 mm. above the jugular point, and deep to the sternal head of the sterno-mastoid (fig. 1). If, however, the patient's head be rotated somewhat to the right, rendering the sterno-mastoid lax, then the bulb may be reached in the interval between the sternal and clavicular heads of the muscle. The distance of the bulb from the end of the clavicle is increased if the thyroid body be large or if the neck be short; if the neck is long or the thyroid small, the distance is decreased. The bulb lies

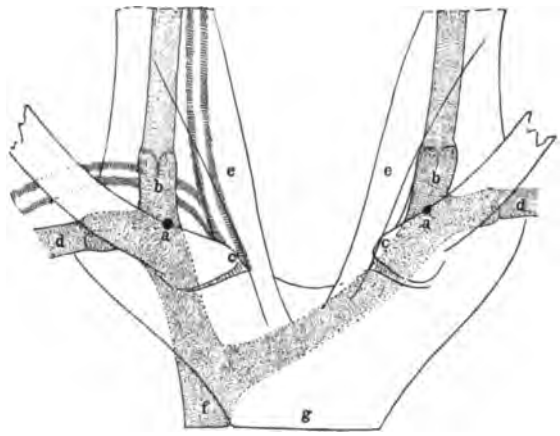


FIG. 1.—Diagram showing the average position of the jugular bulb.

a, the jugular point, 25 mm. from the sternal end of the clavicle (*c*); *b*, jugular bulb, behind sternal head of sterno-mastoid and in front of first stage of subclavian artery; *d*, subclavian vein; *e*, sternal head of sterno-mastoid; *f*, superior vena cava; *g*, manubrium sterni.

directly over the first stage of the subclavian artery (fig. 1), and hence the constant appearance of the arterial pulse in the tracing of the jugular pulse. Mackenzie regards the arterial wave in the jugular tracing as derived from the carotid artery; this may be the case, for above the jugular bulb the vein and carotid artery lie side by side in close contact. Or it may be, as Belski has pointed out, that the arterial pulse wave seen in the jugular pulse is conveyed from the ascending aorta, which lies in contact with the superior vena cava (fig. 2).

The Venous Cistern from which the Heart is filled.—The jugular bulb is part of a large venous cistern represented in fig. 2, and consequently such tracings represent the fluctuations in the pressure of blood contained within this cistern. The cistern is formed by the superior and inferior vena cava,

the innominate, iliac, hepatic and renal veins; it is shut off from the venous system of the lower extremities by strong valves situated in the common femoral veins from 10 to 25 mm. below Poupart's ligament (fig. 2); from

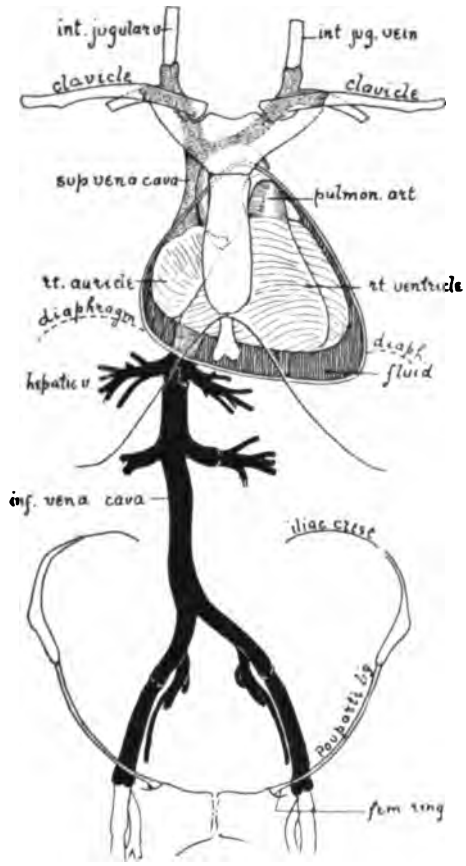


FIG. 2.—Diagram of the venous cistern from which the heart is filled, as seen in a man aged 55, in whom the pericardium was distended and the heart compressed by a large effusion of fluid. The abdominal or infra-diaphragmatic part of the cistern is indicated in black; the thoracic or supra-diaphragmatic is stippled. The heart is compressed upwards and backwards against its attachments.

the venous system of the upper extremity by equally strong valves in the terminal part of the subclavian vein; from the venous system of the head and neck by the valves above the jugular bulb. The jugular valves are evidently the weakest of the three pairs, for when this cistern is subjected

to sudden compression, as in shunting and lift accidents, it is they that give way and lead to the characteristic venous discoloration of the head and neck, which not uncommonly attends such accidents. Non-functional valves may occur in the external iliac or renal veins. To estimate the capacity of the cistern, I selected a male adult subject in which there was an effusion of nearly 600 cc. of fluid within the pericardium, and in which there was, consequently, a great distension of the veins, a condition always present when the jugular pulse is well marked. The veins were emptied of blood and filled with fluid through the right renal vein at a pressure varying from 6 to 8 mm. Hg.; the cistern, as above defined, had a capacity of 430 cc. The weight of the liver, by compressing the inferior vena cava, offered a considerable resistance to the flow of fluid from the abdominal to the thoracic part of the cistern. I estimated that the thoracic part of the cistern contained about 30 cc.; the abdominal part, 400 cc. Taking the output of the heart at 50 cc. for each beat, one may infer that the cistern contains blood to serve for rather more than eight beats.

The Action of the Musculature of the Body-Wall on the Venous Cistern.—Since the greater part of the venous cistern lies within the abdominal cavity it is to be expected, from the experimental results of Hill and Barnard,[1] that active or passive compression of the abdominal cavity will increase the pressure of the blood within the cistern and also within the right side of the heart, and thus alter the amplitude of the waves seen in a tracing of the jugular pulse. This result Dr James Mackenzie has shown to me in his tracings. Dr Leonard Hill found that blood could be squeezed from the liver of the living animal as from a sponge, and in this way the cistern may be quickly filled and distended. I estimated, from injections made on five adult subjects, that the portal system—including in this system all the vessels that lie between the capillaries of the alimentary canal and the capillaries of the liver—contains 500 cc. of blood when moderately distended; probably an amount equal to this could be pressed easily out from the human liver and thrown within the venous cistern, as above defined. The extent to which the abdominal part of the venous cistern is compressed by the tone and contraction of the muscles of the belly-wall may be estimated by observations on the intra-abdominal pressure as measured within the rectum and within the stomach. In the upright posture the intra-rectal pressure, in a position of rest, varies from 14 to 24 mm. Hg., fluctuating with the respiratory movement; if the body be bent or if a weight is lifted, the pressure may mount up to 80 or even 100 mm. Hg. Within the stomach, the pressure varies from 3 to 6 mm. Hg. when standing at rest; a negative pressure can be made to appear if a forced

[1] *Journ. of Physiology*, vol. xxi., 1897, p. 325.

thoracic breath be taken; if the trunk is flexed or if a weight be lifted, a pressure of 40 to 60 mm. Hg. can be obtained.

When the venous cistern is compressed by such movements of the body-wall, its contents can escape only into the right side of the heart. Mr Barnard found, on squeezing the abdomen, that the right side of the heart became distended, and that it was possible in this way to force blood through the passive right heart and lungs into the left auricle. In this experiment the wall of the right auricle, being less resistant than that of either the venous cistern or of the right ventricle, became the most distended; as long as the pericardium was intact, great over-distension or rupture of the right auricle was prevented. In many of the hearts sent to me by Dr Mackenzie, the right auricle was found to be greatly and permanently distended and the right ventricle compressed, a result probably due to a long-continued high pressure within the venous cistern and right side of the heart. In brief, the distension of the right auricle is caused by the contraction of the musculature of the belly-wall, acting through the venous cistern as above defined.

Attachments of the Heart and of the Auricular Musculature.—Before discussing the arrangement of the auricular and ventricular musculatures and the functional significance of that arrangement, it is necessary to mention certain neglected facts connected with the fixation of the heart within the thorax,[1] and the fulcra or *fixed points* from which the cardiac musculature acts. When the heart, while still attached within the pericardium, is pulled forwards, as is diagrammatically represented in fig. 3, it is seen to have two attachments—(1) by the *venous mesocardium* (from *e* to *e* in fig. 3), by which the commencement of the cardiac tube is attached to the pericardium, through which the veins enter the auricles; (2) the *arterial mesocardium* (from *d* to *d* in fig. 3), by which the termination of the cardiac tube is fixed, through which the systemic and pulmonary aortæ leave the pericardial sac. Save at these two mesocardial areas the heart is free. That part of the pericardium to which the auricles are attached is bound to three structures—(1) to the roots of the lungs and by the lungs to the wall of the thorax; (2) to the diaphragm, especially to the crura of that muscle; (3) to the structures in the root of the neck through the superior vena cava and the fibrous tissue surrounding that vessel. The longitudinal (antagonistic) musculature of the auricles has its fulcra or attachments in the venous mesocardium; if the chest be opened, the normal auricular fulcra are lost. The auricular musculature, when freed from its natural attachments, can no more perform its normal action than can a skeletal muscle when separated from its attachments.

[1] See *Lancet*, 5th March 1904, p. 629.

The Base of the Heart and of the Ventricles.—There is great need for a stricter use of the word " base " when applied to the heart as a whole and also when applied to the ventricles. As used clinically, the term " base " is applied to the attached part of the heart, and includes the commencement and end of the heart. At least one ought to distinguish the two parts—the commencement or *venous base* and the terminal or *arterial base* (see fig. 3).

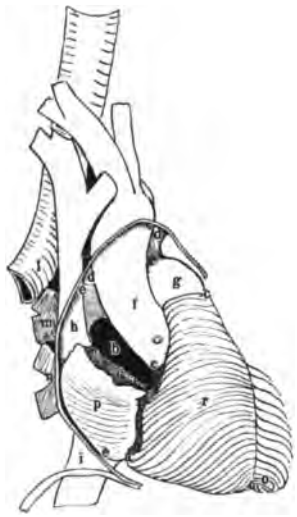


FIG. 3.—Showing the attachments of the heart (diagrammatic). (One-third natural size.)

a, *a*, auricular base of ventricle; *b*, sinus transversus; *c*, *c*, aortic base of ventricles; *d*, *d*, arterial mesocardium; *e*, *e*, venous mesocardium; *f*, ascending aorta; *g*, pulmonary aorta; *h*, superior vena cava; *i*, inferior vena cava, perforating diaphragm and pericardium; *l*, *m*, *n*, structures at the root of the lung—bronchus, pulmonary artery, and pulmonary veins; *o*, vortex at apex; *p*, pectinate musculature of right auricle; *r*, superficial musculature of right ventricle.

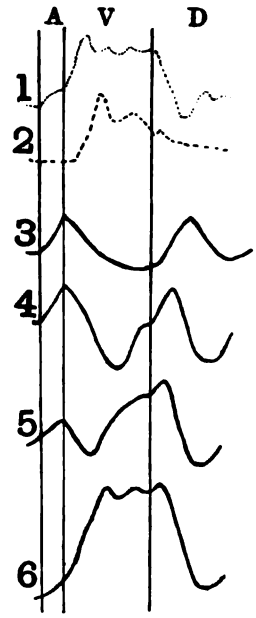


FIG. 4.—Tracings of the jugular pulse (Wenckebach).

1, tracing of apex beat; 2, of radial pulse; 3, 4, 5, 6, of various types of the jugular pulse; A, period of auricular systole; V, period of ventricular systole; D, period of diastole.

As applied to the ventricles the term " base " is still more misleading; in it are included the commencement and end of the ventricular part of the cardiac tube. It would be equally correct to apply a common term to the two orifices of the stomach. The two parts of the base of the ventricles are shown in fig. 3; the commencement of the ventricular tube may be defined as the auricular base (*a*, *a*, in fig. 3); the termination of the ventricle, the aortic base (*c*, *c*, in fig. 3). I pointed out some years ago that the wave of negative variation which commenced and terminated in the base

of the ventricle was easily explicable when one remembered that the base contained the commencement and end of the ventricular tube (*Lancet*, 5th March 1904, p. 631). Lately, Professor Gotch, who was unaware of my surmise, has demonstrated in the frog's heart that the negative wave commences at the auricular base and ends at the aortic.

From tracings which Dr Leonard Hill took of the turtle's heart, it is clear that the apical part of the ventricle is in a state of contraction before the part of the heart at the aortic base.

The Characters of the Jugular Pulse.—A study of the jugular pulse provides the anatomist with a master-key to the architecture of the heart. It cannot be said that our present description of the cardiac musculature helps us to understand either the movements or action of the heart. This defect is due, I believe, to two circumstances—(1) because we do not study its structure while the heart is still fixed by its normal attachments in the thorax; (2) because we have concentrated our attention on the relationship of the ventricles to the arteries and neglected their relationship to the auricles and to the venous cistern. A study of the jugular pulse is concerned with the structural relationship of the ventricles to the auricles, and of the auricles to the venous cisterns from which the two auricles are filled. The main purpose of this paper is to show that each auricle and ventricle contains two sets of muscular fibres: (1) *circular* or "driving" fibres—for compressing the chamber and expelling the blood; (2) *longitudinal* or "antagonistic" fibres, the longitudinal of the right auricle (the auricle concerned in the jugular pulse) being the opponents or antagonists of the longitudinal of the right ventricle, and stand to each other in the same functional relationship as the biceps and triceps of the arm. The doctrine is not a new one; it has been taught by many physiologists, but, so far as I know, no one has ever applied the conception to a study of the structure of the heart. The experimental observations of Porter[1] and of Burton-Opitz,[2] the clinical observations of Mackenzie and Wenckebach, and the exact account of the structure of the heart given by Bruce MacCallum,[3] with my own dissections, provide ample material for the correlationship of the movements and structure of the heart. The observations of Haycraft[4] on the movements of the heart within the chest have also been of great service to me.

[1] W. T. Porter, "Researches on the Filling of the Heart," *Journ. of Physiol.*, vol. xiii. p. 513, 1892.

[2] R. Burton-Opitz, "The Flow of Blood in the External Jugular Vein," *Amer. Journ. of Physiol.*, vol. vii. p. 435, 1902.

[3] J. Bruce MacCallum, "On the Muscular Architecture and Growth of the Ventricles of the Heart," *Johns Hopkins Hosp. Reports*, vol. ix. p. 307, 1900.

[4] P. B. Haycraft, *Journ. of Physiol.*, vol. xii. p. 438, 1891.

In fig. 4 is reproduced tracings of four types of the jugular pulse (3, 4, 5, 6), with their time relationships to the apex beat (1) and radial pulse (2), given by Professor Wenckebach in his article in the *Archiv für Anatomie und Physiologie*, 1906, p. 317. Tracing No. 3 is that of the jugular pulse in a condition of health; in the period of auricular systole, the jugular bulb is seen to fill; in the period of ventricular systole, the bulb is emptying; in the period of diastole, the bulb at first fills and then suddenly empties and again begins to fill preparatory to the next auricular systole. I propose now to discuss the cardiac musculature which is in action during each of these three periods.

The Musculature in Action at the Commencement of Auricular Systole. —As shown by the tracings in fig. 4, there is an expansion of the jugular bulb during the contraction of the auricle. Are the orifices of the superior and inferior vena cava in the right auricle then closed—or are they then open so that the wave caused by the contraction of the auricle may pass unhindered to the jugular bulb? At the present time it is taught that these orifices are then closed by circular muscle fibres—a musculature derived from the sinus venosus and contracting before that of the auricle. There are no circular muscle fibres round the inferior caval orifice of the human heart, and those which surround the termination of the superior vena cava (see A, fig. 7) are not strong enough to quite occlude the superior caval orifice and act as a sphincter. In cases where the venous cistern is well filled and the jugular pulse well marked, Mackenzie could hear the jugular valves close with a click during auricular systole; in such cases there is evidently a direct spread of the auricular wave to the jugular bulb. The absence of a mechanism for preventing the regurgitation of blood from the auricles of birds and mammals is remarkable; for in fishes, amphibians, and reptiles this is effectively prevented by the two membrano-muscular venous valves which guard the sino-auricular orifice. In the warm-blooded vertebrates the sinus venosus no longer exists as a separate chamber; with the appearance of the diaphragm the greater part of the cavity of the sinus becomes overgrown by the musculature of the right auricle. The venous valves become broken up; but out of the right venous valve is evolved a very remarkable band of musculature — the *right tænia terminalis*—shown in figs. 5, 6, and 8. When the right auricle is thrown into an artificial state of contraction by the injection of a hot liquid mass, the tænia falls within the right auricle, across the mouth of the superior vena cava, occluding that orifice, and in former papers[1] I inferred that it

[1] "The Evolution and Action of Certain Muscular Structures of the Heart," *Lancet*, 27th February, 5th March 1904; *Proc. Anat. Soc. of Great Britain and Ireland*, November 1902.

was the only effective means in the mammalian heart for preventing regurgitation of the blood from the right auricle. When the resuscitated heart is fixed in a manner similar to that which obtains in the unopened thorax, the tænia terminalis is seen to inflect the auricle in front of the caval orifices but not to an extent sufficient to completely occlude these orifices, and I conclude, therefore, that there is no muscular or valvular mechanism in the avian or mammalian heart which can completely prevent regurgitation of the blood from the right auricle if that chamber be dis-

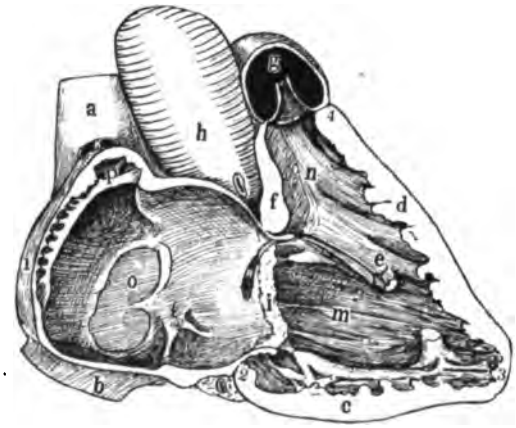


FIG. 5.—Drawing of a heart, from a case recorded by Dr Mackenzie. The jugular pulse was of the type shown in 6, fig. 4. The auricle is greatly distended. (One-half natural size.)

a, superior vena cava; *b*, inferior vena cava; *c*, diaphragmatic wall of right ventricle; *d*, sternal wall of right ventricle; *e*, on the root of the moderator band with the right division of the *a.v.* bundle entering it; *f*, infundibulo-aortic wall of right ventricle; *g*, pulmonary artery; *h*, aorta; *i*, septal valve of tricuspid, atrophied; *k*, position of sino-auricular node; *m*, body of right ventricle; *n*, infundibulum; *o*, septum ovale; *p*, tænia terminalis; *r*, auriculo-ventricular node, with the commencement of the *a.v.* bundle. Measurements are taken between 1 and 2, 2 and 3, 3 and 4, for recording the relative size of the auricle and ventricle.

tended. The venous cistern, described at the commencement of this article, has evidently taken the functional place of the sinus venosus, and the six pairs of valves which prevent regurgitation of blood from that cistern have evidently taken the place of the venous valves at the sino-auricular junction. Regurgitation from the right auricle during systole can only occur when the diastolic pressure in the right ventricle is greater than that in the venous cistern. The pressure within the abdominal part of that cistern is always positive, and hence the inferior caval orifice is guarded neither by sphincter nor competent valve; and in the thoracic part of the cistern the pressure may be negative, and hence the superior caval orifice

is furnished with a muscular mechanism which may be competent at low pressures. I conclude, therefore, that Mackenzie is right in regarding the expansion of the jugular bulb during auricular systole, in cases where the right auricle is distended, as directly due to the contraction of the auricle; but in conditions of health it is probably due to the arrest of the venous outflow.

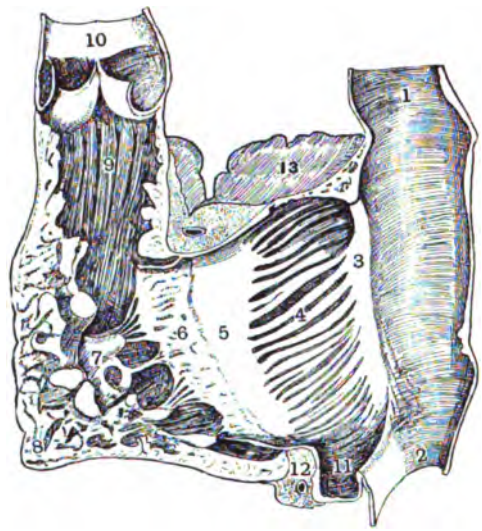


FIG. 6.—Right wall of the heart viewed on its inner aspect. From a specimen obtained from a subject in which there was evidence of a long-standing venous back pressure - from arterial sclerosis of the coronary arteries, with consequent great dilatation of the auricle. The heart was hardened *in situ* by the injection of formalin. (One-half natural size.)

1, superior vena cava; 2, inferior vena cava: 3, right tænia terminalis; 4, musculi pectinati; 5, auricular canal (annular fibres); 6, marginal and infundibular cusps of tricuspid; 7, musculi papillares; 8, trabecular network at apex of right ventricle; 9, internal longitudinal system running from apex to pulmonary artery; 10, pulmonary artery; 11, sub-Eustachian sinus, between Eustachian valve and base of right ventricle; 12, auriculo-ventricular groove; 13, appendix of right auricle.

The Pectinate Musculature of the Right Auricle.—Although the right tænia terminalis and musculi pectinati make up the chief mass of the musculature of the right auricle, the part they play in auricular systole is neglected at present. In fig. 6, the right wall of the heart is represented —similar to that which has been removed to make the drawing shown in fig. 5. The right tænia terminalis and pectinate musculature are shown as they appear on the inner wall of the heart. The musculi pectinati, fifteen to eighteen in number, each from 1 to 2 mm. in diameter, take their

origin in the right tænia terminalis (figs. 5 and 6) and end in the circular musculature of the auricular canal (5 in fig. 6). Their relationship to the heart as a whole is shown in figs. 8 (horizontal section) and 7 (heart viewed on its right side) They have their origin or fulcrum in the tænia terminalis; when they contract, the auricular canal, auriculo-ventricular groove, and base of the right ventricle are drawn towards the tænia terminalis (towards the venous mesocardium), as is shown diagrammatically



FIG 7.—Diagram to show the antagonistic action of the musculatures of the right auricle and ventricle.

A, the position of the auriculo-ventricular groove at the end of auricular systole; B, its position at the end of ventricular systole. *a*, elliptical fibres round terminal part of superior cava; *b*, inferior vena cava perforating diaphragm and pericardium; *c*, position of right tænia terminalis; *d*, apical vortex; *e*, base of right ventricle in systole; *e'*, base in auricular systole; *f*, pulmonary artery; *g*, aorta in ventricular systole; *g'*, aorta in auricular systole; *h'*, musculi pectinati in auricular systole; *h''*, in ventricular systole; *k*, pulmonary artery; *i*, pulmonary veins.

in fig. 7. The musculi pectinati not only expel the blood from the auricle but also draw the base of the ventricle on to its load of blood. The musculi pectinati in the normal diastolic auricle are from 20 to 25 mm. long; in the greatly distended auricles obtained from cases of long-standing venous back pressure, such as the specimen shown in fig. 6, they measure from 30 to 40 mm. In the auricle, artificially thrown into a state of contraction by the injection of a hot mass, the musculi pectinati shorten to half their diastolic length. I conclude, therefore, that in the normal heart the

musculi pectinati draw the auricular base of the right ventricle backwards to the extent of about 6 to 8 mm.

The Antagonistic Musculature of the Right Ventricle.—Every muscle in the body has its opponent, and to this law the pectinate musculature of the right auricle is no exception. It is opposed by two groups of musculature in the right ventricle—the outer spiral layer, shown diagrammatically in fig. 7, and the inner longitudinal musculature—musculi papillares and longitudinal columnæ—shown in fig. 6. Both these groups of musculature commence in the apex of the heart, which, during systole of the ventricle, certainly does not retreat towards the base. The apex of the heart is the *fixed point* from which this musculature acts as the opponents of the musculi pectinati; how the apex becomes a fixed point will be discussed later. All physiologists agree that in ventricular systole, the auricular base of the ventricle moves towards the apex. The minute one grasps this conception of the action of the musculature of the heart, the apparent complicated arrangement of the superficial spiral fibres, which take their origin in the vortex at the apex of the heart and turn with a spiral twist to reach an insertion in the membranous tissue at the auricular base of the right ventricle, becomes plain; so does the arrangement of muscular trabeculæ within the heart. They are so arranged as to draw the auricular base of the ventricle towards the apex, and thus elongate the musculi pectinati and expand the auricle. There is nothing new in the statement that the auricle expands to occupy the space vacated by the ventricle, but somehow it has escaped the attention of anatomists that the musculature of the auricle and ventricle is specially arranged to accomplish this purpose. As long as the ventricle contracts, the more and more must its auricular base approach the apex of the heart and the more must the auricle be expanded.

Various Forms of Jugular Pulse, and their Relationship to Distension of the Auricle.—From his observations on the *normal* heart, Professor Wenckebach concludes that the jugular bulb is emptying during the whole period of ventricular systole (tracing 3, fig. 4), because the auricle is being expanded as long as the ventricle is contracting. Burton-Opitz estimated, from experiments made on dogs, that 90 per cent. of the venous outflow in the veins of the neck took place during the period of ventricular systole, showing the importance of this movement in the filling of the heart. Certainly contraction of the ventricle is not necessary for an expansion of the auricle, for in many cases of jugular pulse analysed by Mackenzie and by Wenckebach, the auricle was found to contract without the ventricle; yet the auricular systole is followed by a certain degree of collapse of the jugular bulb, showing that the auricle had dilated without

any active co-operation on the part of the ventricle. Such observations are made only in cases of heart-block—partial or complete—and in such cases the venous cistern and auricle are over-distended. It must be remembered, however, that in such cases, although systole of the auricle is not followed by a systole of the ventricle, yet it is followed by a reposition of the base of the ventricle, for during the auricular systole the base of the ventricle is drawn into the position that marks the commencement of a ventricular systole; when the auricular systole is over and its diastole has commenced, the auricular base of the ventricle, under pressure of the venous blood, returns to its position of rest, and this movement is accompanied by collapse of the jugular bulb. It is anatomically impossible that there can be a contraction of the pectinate musculature without a corresponding movement of that part of the ventricle on which this musculature acts.

In tracing 6, fig. 4, Wenckebach represents a very different type of jugular pulse, and one that Mackenzie has regarded all along as of the greatest significance. In the cases from which this type of tracing is obtained, the jugular bulb is expanding or filling instead of emptying during the period of ventricular systole. Now, in every one of the hearts sent to me by Mackenzie and from which he had obtained this type of jugular tracing, there was one absolutely constant feature—there was great dilatation of the auricle with a certain degree, sometimes more, sometimes less, of compression of the ventricle. In these hearts the auriculo-ventricular groove occupied the position corresponding to that of ventricular systole in the normal heart (see B, in fig. 7). Figs. 5 and 6 are from hearts in which the + instead of the − jugular wave occurred during ventricular systole. In all cases where this type of jugular pulse occurs there is great distension of the venous cistern and of the auricle; the auricular base of the heart is pushed forwards so far in diastole that during ventricular systole it cannot move forwards more, and therefore there can be no expansion or dilatation of the auricle and no emptying of the jugular bulb during ventricular systole. The permanent distension of the auricle under a high venous pressure has destroyed the antagonistic action between the auricular and ventricular musculature and suction action of the heart.

In fig. 4, Wenckebach represents two tracings (4, 5) which are intermediate to the negative type (tracing 3) and positive type (tracing 6) of jugular pulse. In these intermediate types the jugular bulb commences to expand during ventricular systole; in tracing 4, the bulb expands during the last third of ventricular systole—in 5, during the latter half of that period. The explanation which Wenckebach offers is that the appearance of the expansion of the bulb during ventricular systole depends on the degree to

which the venous cistern and auricle are distended. The greater the head of pressure the quicker will the auricle become distended; or, putting the same explanation into anatomical terms—the more the auricle is distended by the head of pressure in the venous system the more is the auriculo-ventricular groove pushed towards its forward limit (see fig. 7), and hence, with the forward swing of the base of the ventricle in systole, there is only a limited positive expansion of the auricle and, consequently, only a shortened period in which the jugular bulb collapses. That is to say, the pressure of blood in the venous cistern not only alters the amplitude but also the type of jugular pulsation.

Mackenzie, however, has accumulated a great deal of evidence to show that when the positive type of jugular pulse appears (tracing 6, fig. 4), there is much more than merely a distension of the great veins and auricles. He finds that this type of pulsation appears suddenly; that all signs of an auricular contraction disappear from his tracings; or if they are present they occur subsequent to, or at the same time as, the contraction of the ventricle. In his opinion the inception of the heart-rhythm has been altered, and, instead of commencing at the great veins (sino-auricular node described by Flack and the writer?), begins at the auriculo-ventricular junction (auriculo-ventricular node—Knotten of Tawara?). (See K and R, fig. 5.) In such hearts I have been unable to detect any positive microscopic lesion in either the sino-auricular or auriculo-ventricular node. The one feature always present is great dilatation of the auricle (fig. 5); hypertrophy of the tænia terminalis and musculi pectinati (fig. 6). It is possible that, in such cases, the venous pressure within the auricle has become so great that conduction and contraction of the auricular musculature is so depressed that for all practical purpose the auricle is paralysed, as Mackenzie originally supposed.

The Diastolic Movement of the Heart.—In Professor Wenckebach's tracings (fig. 4) it will be seen that the jugular bulb still continues to expand or fill for a brief interval after the diastole of the ventricles have commenced; this brief diastolic expansion is followed by a fall. Everyone is agreed as to the meaning of the diastolic fall—it is the result of the opening out and filling of the ventricles; but what explanation is to be given of the brief expansion of the bulb which precedes the fall? Wenckebach's explanation is that it is due to reposition of the base of the heart, and this, on anatomical grounds, I believe to be the right one. In fig. 7 (page 11) only the extreme positions of the auriculo-ventricular groove are represented; between A, its position in auricular systole, and B, its position in ventricular systole, there is an intermediate or *diastolic* position—not represented in the figure. When ventricular systole is ended,

the auriculo-ventricular groove and the bases of the ventricles fall back immediately into the diastolic position; this movement evidently causing a temporary compression of the auricles, and the expansion seen in the jugular bulb at the commencement of diastole.

The Manner in which the Apex of the Heart becomes a Fixed Point to serve as a Fulcrum for the Spiral and Longitudinal Musculature of the Ventricles.—It is not my purpose now to discuss the meaning and cause of the apex beat; I merely wish to show that the theory I am now advancing of the heart's movements gives a full and satisfactory explanation of the peculiar arrangement of the musculature of the ventricles, especially in the region of the apex. At the present time no explanation is offered of the muscular vortex which occurs at the apex of the left ventricle (see figs. 6, 7, 8, 9), of the remarkable thinness of the ventricular wall at the apex (that of the left ventricle is only 1 to 2 mm. thick), of the superficial spiral fibres of the heart (which, commencing at the apex, end on the auricular bases of the ventricles), or of the peculiar and constant arrangement of the trabeculæ and columnæ carneæ within the heart. When it is realised that the apex of the heart in systole becomes a fixed point or fulcrum from which the longitudinal and spiral fibres of the ventricles may act and thus expand the auricles, these structures, previously obscure and meaningless, become significant and easily understood.

I have already mentioned the superficial spiral fibres of the heart; their arrangement is shown in figs. 7 and 10. The arrangement of the longitudinal system within the right ventricle is represented in figs. 5 and 6; that of the left in figs. 8, 9, 11. In both ventricles the arrangement is the same; in both there are two systems of internal longitudinal fibres—(1) those which pass in the form of papillary muscles and fleshy columns to the *auricular base* of the ventricles; (2) those which pass from the apex to the *aortic* base of the ventricles. The significance of the system passing to the auricular base of the ventricles is clear, namely, to draw them towards the apex and thus expand the auricles; but what is the meaning of those passing from the apex to the aortic base? (See *e*, *n*, in fig. 5; 9 in fig. 6; *k* in fig. 9, and *m* in fig. 11.) These apical-aortic fibres lie parallel to the column of blood expelled by the ventricles in systole; they certainly do not draw the apex of the heart towards the aorta. If anything, the apex of the heart moves forward and upwards in systole. Nor do they draw the aortic base towards the apex, for all physiologists agree that the distance between the apex and aortic base of the ventricles is not diminished, or only slightly diminished, during systole. Were the ventricle made up of purely circular or driving fibres, then the distance from apex to base would increase during systole; for a tube composed of purely circular fibres must increase in

length as it contracts, for as the fibres diminish in length they gain in thickness. These longitudinal fibres of the heart, passing from apex to aortic base, seem to me to stand in the same relationship to the circular or driving fibres of the ventricle as the longitudinal muscular coat of the bowel stands to the circular. That is to say, the fibres passing from apex

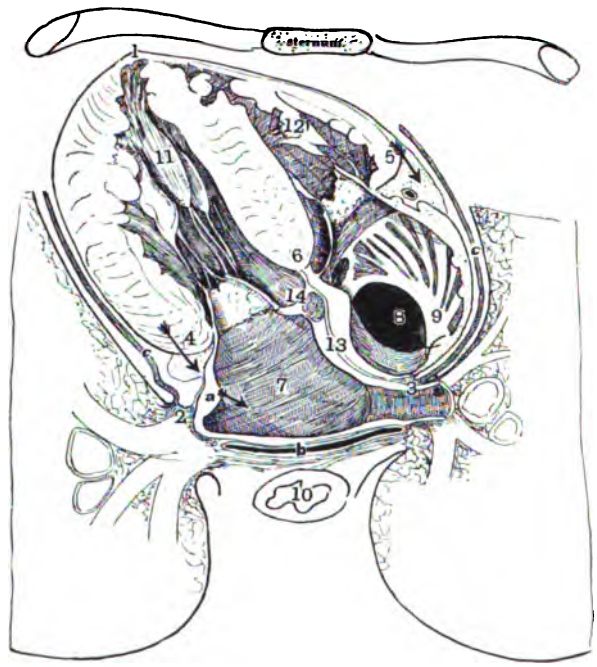


FIG. 8.—Horizontal section of the heart *in situ*.

1, apex of heart, at site of vortex; 2, attachment to root of left lung; 3, attachment to root of right lung; 4, base of left ventricle, the arrow showing the direction of movement in auricular systole; 5, base of right ventricle, the arrow showing the direction of movement in auricular systole; 6, interventricular septum at its junction with interauricular septum; 7, left auricle; 8, inferior caval orifice in right auricle; 9, right tænia terminalis and musculi pectinati; 10, œsophagus; 11, musculi papillares of left ventricle; 12, musculi papillares of right; 13, interauricular septum; 14, commencement of aorta. *a*, left tænia terminalis—the arrow shows the direction of its contraction; *b*, sinus obliquus between left auricle and pericardium; *c*, pericardium.

to aortic base act as antagonists to the circular or driving fibres; the one tends to shorten the apex-base diameter of the heart, the other to increase it; by the balance between these two systems the apex of the heart is maintained as a fixed point from which the other longitudinal systems may act on the auricular bases of the ventricles.

The Attachments and Relationships of the left Auricle.—The manner

in which the left auricle empties its contents into the left ventricle, when the heart is *in situ*, is not easily understood, and is scarcely alluded to by any who have made a special study of the heart. A horizontal section of the heart gives the clearest picture of its relationships. It is situated between the roots of the lungs, being attached very firmly to each; through the lungs, in the unopened thorax, it is bound to the walls of the thorax. Behind it lies the unyielding structures of the posterior mediastinum. A coronal section (fig. 9) shows that the upper border of the auricle is also in contact with unyielding structures—the pulmonary arteries and bronchi. To the trachea and bronchi the upper border of the left auricle is extremely firmly bound by an expansion of the venous mesocardium (see fig. 9, *b*, and fig. 10, xxx). Thus the posterior, upper, and lateral aspects of the left auricle are in contact with structures which are more or less unyielding, and we cannot suppose that these walls approximate or move towards the centre of the auricle during systole. Only two surfaces of the left auricle are in contact with structures which are freely movable—the floor, which is in contact with the base of the left ventricle; and the anterior or aortic wall, which is in contact with the ascending aorta (fig. 9). On the anatomical evidence, which is the only evidence at present available, one must infer that in systole of the left auricle its floor and anterior wall are drawn towards its posterior and upper wall. That is to say, in systole of the left auricle the auricular base of the left ventricle is drawn upwards and the aorta drawn backwards in the manner represented diagrammatically in fig. 9.

Systolic Movements of the Aorta. — In figs. 7 and 9, representing profiles of the heart, viewed from the right and from the left, the systolic movements of the ascending aorta are represented. In systole of the auricles the commencement of the aorta swings backwards to the right, in systole of the ventricle it moves forwards and to the left. The final proof that such movements occur must be obtained by experiment on the living heart naturally attached within the unopened thorax—an experiment by no means easy of performance. The anatomical evidence that such movements must occur seems to me convincing. It is as follows: (1) When the left auricle (while the heart is still *in situ*) is filled with injection, the aorta is pushed forwards as the auricle fills; it retrocedes towards the posterior wall of the auricle as that cavity is emptied; (2) in mitral stenosis or cases where the left auricle becomes greatly dilated, that dilatation is attended by a forwards displacement of the aorta (see fig. 11); (3) for the reasons already given, it is impossible to conceive a contraction of the left auricle except by an upward movement of the auricular base of the left ventricle, and a backward movement of the aorta; (4) an

extension of the pericardium (the sinus obliquus, fig. 8) passes up behind the left auricle to act as a bursa in this movement; (5) the musculature of the interauricular septum is apparently without purpose unless one

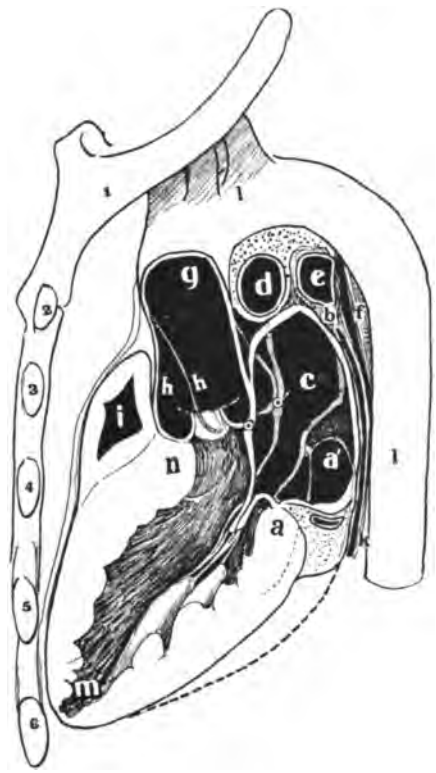


FIG. 9.—Section of the heart *in situ*, exposing the left chambers and commencement of the aorta. The position of parts in systole of the auricle is indicated.

a, position of the auricular base of the left ventricle towards the end of ventricular systole; *a'*, its position towards the end of auricular systole; *b*, tissue of the venous mesocardium binding the upper border of the left auricle to the bronchi and trachea; *c*, left auricle in diastole—the shaded outline represents the auricle in systole; *d*, right pulmonary artery; *e*, left bronchus; *f*, œsophagus; *g*, ascending aorta; *h*, position of anterior wall of aorta in systole of the ventricles; *h*, its position in systole of the auricles; *i*, infundibulum of right ventricle; *l*, aorta; *m*, apex of left ventricle with origin of the internal longitudinal system; *n*, aortic base of ventricle; *o*, base of the anterior cusp of the mitral in ventricular systole; *o'*, its position in auricular systole.

grants—as a working hypothesis—that this aortic movement occurs. The position and arrangement of the interauricular septum is indicated by the number 13 in fig. 8. The greater part of the musculature of this septum is attached to the central fibrous body at the root of the aorta (14 in fig. 8);

from that attachment the fibres run along the septum to end in the right and left auricles near the root of the right lung and in the inferior vena cava. They terminate in those parts of the auricle which are fixed by the venous mesocardium. It is impossible to conceive that these fibres can draw inwards the mesocardium: on the other hand, the root of the aorta is movable; the functional significance of that movement is apparent from figs. 7 and 9. Were the interauricular septum merely a passive partition between the auricles—as it is usually supposed to be—there would be no need for the definite and constant arrangement of muscular bundles of which it is composed. On the other hand, the theory of the heart movements which I advance gives a satisfactory explanation of the musculature of the interauricular septum.

The Antagonistic Arrangement of the Musculature of the Left Auricle and Ventricle.—In the arrangement of its musculature and manner of contraction the left auricle differs totally from the right. Here there is no pectinate musculature, for the greater part of the left auricle in mammalian and avian hearts is formed by an expansion derived from the pulmonary veins. The arrangement of the musculature, as seen in a left auricle in the condition of systole, is shown in fig. 10. It will be seen, in the first place, that many of the muscular bands of the left auricle end in the termination of the inferior vena cava, which, in turn, is fixed to the pericardium and diaphragm. One of the bands which ends thus is shown in fig. 10 (*h*); it is the left tænia terminalis—a band of muscle which, taking its origin in front of the superior vena cava in common with the right tænia, sweeps to the left in the anterior wall of the left auricle and then turns down between the left auricular appendix and left pulmonary veins to end as above described. It is also shown in the horizontal section of the heart (fig. 8, *a*); the arrow in that figure indicates the direction of its movement in systole of the left auricle.

The upper and lateral borders of the vestibule of the left auricle are fixed to the roots of the lungs by the pulmonary veins, and by strong fibrous tissue of the venous mesocardium (the line of attachment is shown in fig. 10 by a series of x's). When the musculature of the left auricle contracts —the tænia terminalis and muscular laminæ which end in the auricular canal—its collective effect is to draw upwards the auricular base of the left ventricle into the position indicated by A′ in fig. 10. On this part of the base of the ventricle end (1) the superficial spiral fibres which commence in the apex and in the posterior interventricular sulcus (fig. 10); (2) the internal longitudinal system—papillary and columnar musculature (figs. 8, 9, 11). The apex of the heart serves as the fulcrum for these systems of musculature, and hence in ventricular systole the base is drawn towards

the apex (fig. 10 *a*) with a consequent expansion of the left auricle to occupy the space vacated by the ventricle. With this movement one would expect a rapid flow of blood to the auricle from the veins of the lungs. Is there any evidence of such a flow?

The Cardio-Pneumatic Movements.—If the tracing of these movements obtained by Mosso, and reproduced by Hill in his article on the circulation in Schäfer's *Text-Book of Physiology*, be examined, it will be seen to agree

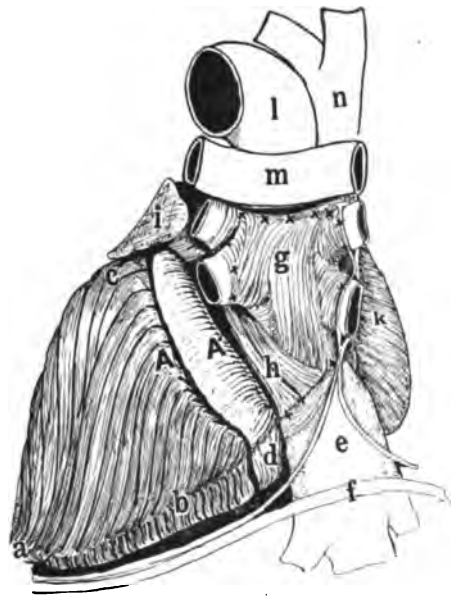


FIG. 10.—The heart from behind, showing the arrangement of the musculature of the left auricle and ventricle.

A', the auricular base of the left ventricle, in systole of the auricle. A, its position in ventricular systole. *a*, apex of left ventricle, over vortex; *b*, posterior interventricular groove; *c*, aortic base of left ventricle; *d*, auricular base of the right ventricle in systole of the auricles; *e*, inferior vena cava perforating diaphragm (*f*) and pericardium; *g*, fibres on the posterior aspect of vestibule of left auricle; *h*, termination of left tænia terminalis; *i*, appendix of left auricle; *k*, right auricle; *l*, aorta; *m*, pulmonary arteries; *n*, superior vena cava. The x x x indicate the attachment of the vestibule of the left auricle to the pericardium and structures in the roots of the lungs.

in every detail with the tracing obtained from the jugular pulse. At the commencement of ventricular systole there is an inspiratory movement of the air; just before the end of the systole there is a slight expiratory movement corresponding to the terminal systolic rise seen in tracings 4 and 5 given by Wenckebach of the venous pulse (see fig. 4). Soon after the commencement of diastole, there is an inspiratory movement, corresponding to the diastolic emptying of the jugular bulb. Those who have worked at the

microscropic structure of the lung know how difficult it is to differentiate sections of the smaller pulmonary veins from sections of infundibula and air-cells, so intimately are the walls of the veins fused in the general structure of the lung. One would therefore expect that the fluctuations of blood-pressure in the left auricle and pulmonary veins would be reflected in the air-content of the lung. The tracings of these movements taken by Haycraft[1] and by Harris,[2] however, differ very materially from that given by Mosso. At the commencement of ventricular systole they find

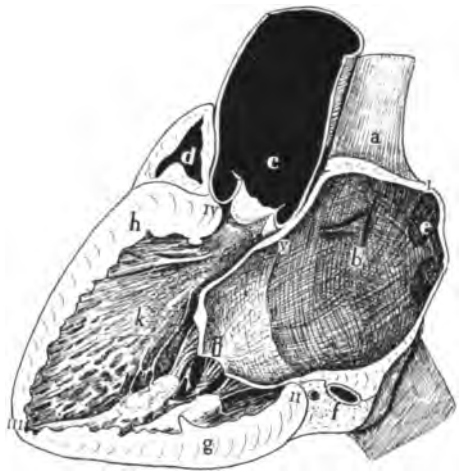


FIG. 11.—Section of the left chambers of a heart in which the auricle is dilated and the ventricle compressed. The right chambers of the same heart are shown in fig. 5. (One-half natural size.)

a, superior vena cava; *b*, left auricle; *c*, aorta; *d*, infundibulum of right ventricle; *e*, right pulmonary veins; *f*, coronary sinus and left auriculo-ventricular groove; *g*, diaphragmatic wall of left ventricle; *h*, sternal wall of left ventricle; *i*, mitral valve (stenosed); *k*, septum of left ventricle with inner longitudinal fibres passing from apex to aortic base. In estimating the dilatation of the chambers, the height of the auricle is measured from I to II, the length of the diaphragmatic wall of the ventricle from II to III, and the sternal wall from III to IV. The aortic base of the left ventricle extends from IV to V, the auricular base from II to V.

an expiratory and not an inspiratory movement. The inspiratory movement sets in and continues during the last two-thirds of the ventricular systole. I cannot account for the initial expiratory movement observed by Haycraft and Harris during ventricular systole, but it seems to me that the inspiratory movement which follows it can be accounted for by an emptying of the pulmonary veins quite as satisfactorily as by a direct action of the contracting ventricle on the lungs.

[1] J. B. Haycraft and R. Edie, *Journ. of Physiol.*, vol. xii., 1891, p. 426.

[2] D. Fraser Harris, *Journ. of Physiol.*, vol. xxvi., 1905, p. 495.

The Effect of Dilatation of the Left Auricle on the Left Ventricle.—In dealing with dilatation of the right auricle, I showed that, as the auricular chamber became distended, the base of the ventricle became pushed forwards until it occupied permanently a systolic position. With dilatation of the left auricle, the base of the left ventricle comes to occupy a similar position. The auricular base is pushed downwards and forwards (see fig. 11, II–V). The chordæ tendineæ and musculi papillares become permanently shortened. In such a heart as is shown in fig. 11, the auricle becomes practically a passive and over-distended chamber, constantly in a condition of diastole; when the ventricle contracts, its base is already in the systolic position; hence there

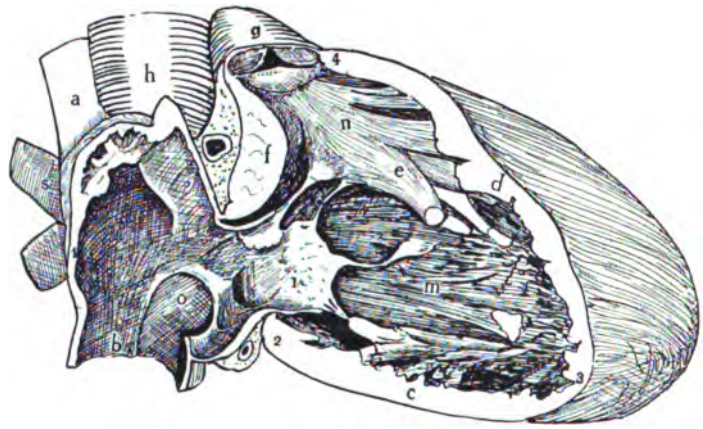


FIG. 12.—Right chambers of a heart in which the jugular pulse was found to be of the normal type. (One-half natural size.) (To be compared with heart shown in fig. 5, p. 9.)

a, superior vena cava; *b*, inferior vena cava; *c*, diaphragmatic wall of right ventricle; *d*, sternal wall; *e*, moderator band; *f*, infundibulo-aortic wall; *g*, pulmonary artery; *h*, ascending aorta; *i*, septal cusp of tricuspid; *m*, sinus of right ventricle; *n*, infundibulum of right ventricle; *o*, septum ovale; *s*, right pulmonary veins.

can be no positive expansion of the auricle due to ventricular systole. If the cardio-pneumatic movements are really due to the expansion of the left auricle by the systole of the ventricle, then the inspiratory movement in such cases should occur only during diastole of the heart—as is the case in over-distension of the right auricle.

The Auriculo-Ventricular Index.—In fig. 12 is reproduced a drawing (half natural size) of another of the hearts sent to me by Dr Mackenzie. It is that of a man in whom the ventricles are enlarged, a consequence of arterio-sclerosis; but the auricles, compared to the ventricles, are relatively small. The drawing is reproduced for two reasons: (1) because the jugular pulse was of the normal type (see tracing 4, fig. 4); and (2) because it

illustrates the method which I have found most useful in making a record of pathological hearts. If the heart shown in fig. 12 is compared with that represented in fig. 5 (p. 9), in which the jugular pulse was of the type shown in tracing 6, fig. 4 (p. 6), a striking difference will be observed in the proportion of auricle to ventricle. In the heart of fig. 5 the auricle is greatly dilated, the ventricle compressed; in the other (fig. 12), although both chambers are hypertrophied and dilated yet the proportion between auricle and ventricle is approximately normal. If I am right in regarding the change in the jugular pulsation as due to the dilation of the auricle and compression of the ventricle, then it is important to obtain an accurate method of expressing *the relationship of auricle to ventricle.* To estimate their relative proportions I take the following measurements:—

(1) *Of the lateral wall of the right auricle and ventricle.*—The points from which measurements are taken are shown in fig. 8 (p. 16); the auricular wall is measured from 3 to 5; the ventricular from 5 to 1. In the heart with the dilated auricle (fig. 5) the auricular measurement is 95 mm., the ventricular 90; that is, the lateral auricular wall stands to the ventricular wall as 105 : 100 (auricular index = 105). In the heart shown in fig. 12 the auricular measurement is 85 mm., the ventricular 105 mm., the auricular index = 80. In normal hearts the *lateral* auricular index varies from 60 to 80; in the dog, cat, kangaroo, bear, horse, calf, ox, I found that this index varied from 30 to 60. The lower the auricular index, then the greater should be the expansion of the auricle during ventricular systole and the more marked the systolic collapse of the jugular bulb.

(2) *Of the septal wall of the right auricle and ventricle.*—The measurements were taken from the points shown in figs. 5 and 12. The auricular septal wall was measured between 1 and 2 (fig. 12), the ventricular from 2 to 3 (fig. 12). In the heart with the dilated auricle (fig. 5) the auricular measurement was 55 mm., the ventricular 72 mm., the *septal auricular index* being thus 76. In the heart shown in fig. 12 the auricular measurement was 50, the ventricular 90 mm.; the septal auricular index being 55. In normal human hearts the septal index varies from 45 to 55.

(3) I found that with dilatation of the auricle the diaphragmatic wall of the right ventricle (*c*, fig. 12) became reduced in extent, while the sternal wall (*d* in fig. 12) was scarcely affected. In the heart with the dilated auricle (fig. 5) the diaphragmatic wall is 83 per cent. of the sternal wall; in the other heart (fig. 12) the proportions are similar, but this result is due, not to a reduction of the diaphragmatic wall, but an elongation of the sternal wall of the heart shown in fig. 12.

(4) *Of the left chambers of the heart.*—The points from which measurements were taken are indicated in fig. 11 (p. 21): the auricular height was

measured from I to II; the ventricular from II to III. In normal hearts the auricular height varies from 50 to 60 per cent. of the ventricular measurement; in hearts where the left auricle is dilated, the auricular measurement varies from 70 to 100 per cent. of the ventricular.

(5) Measurements were also taken of the diaphragmatic and septal walls of the left ventricle between the points shown in fig. 11. In dilatation of the left auricle, the diaphragmatic wall becomes reduced; the sternal wall is reduced to a less extent.

Method of Preparing Hearts for Examination.—The method at present employed in the post-mortem examination of the heart are too crude to yield accurate information concerning cardiac lesions. For its proper examination the heart must be specially prepared and systematically examined—not roughly measured, and cut in pieces as removed from the body. In examining Dr Mackenzie's hearts I have used the following method: (1) The heart is washed for twelve hours in running tap water, all blood being squeezed out from its chambers; (2) the heart is then hardened and preserved by the well-known Kaiserling process, being floated in an ample bath of the solution with the chambers dilated to their normal extent by the injection of fluid or by the insertion of cotton-wool; (3) after they are thus fixed the arteries are systematically examined; (4) the lateral walls of the heart are removed, as shown in figs. 5, 6, 11, and 12, each heart being thus divided into three pieces; (5) serial sections were made of the termination of the superior vena cava at the position of the sino-auricular node (see fig. 5); (6) serial sections are made of the *a.v.* node, *a.v.* bundle, and several sections of the *a.v.* ramifications in the apex of the left ventricle; (7) measurements and drawings were made of the valves, orifices, thickness of the walls and of the chambers of the heart, as indicated in the paragraph dealing with the auriculo-ventricular index.

Summary.

(1) The jugular bulb from which records of the venous pulse are usually taken is situated deep to the clavicular head of the sterno-mastoid, 25 to 30 mm. outwards from the sternal end of the clavicle.

(2) The jugular bulb is part of a venous cistern from which the right side of the heart is filled.

(3) The greater part of this cistern lies within the abdominal cavity and is, consequently, compressed by the musculature of the wall of that cavity.

(4) That it is necessary to recognise two parts in the base of the ventricle—the auricular base and the aortic base (see fig. 5). The one is the commencement of the ventricular tube; the other is its termination.

(5) In the heart there are two systems of musculature—one circular in arrangement and expelling in function, the other longitudinal and concerned in systolic movements of the auricle and ventricle. The longitudinal system of the ventricles is antagonistic in action to that of the auricles. The longitudinal system is concerned in the production of the venous pulse.

(6) The longitudinal musculature acts from three fulcra: (1) the apex of the heart; (2) the venous mesocardium; (3) the arterial mesocardium (see fig. 3).

(7) When the auricles become greatly dilated the antagonistic action between their longitudinal musculature and that of the ventricles is lost, and with this loss the characters of the jugular pulse are altered.

(8) In systole of the heart the ascending aorta must undergo a pendulum swing (see figs. 7 and 9).

(9) The cardio-pneumatic movements probably arise from the expansion of the left auricle caused by the contraction of the left ventricle, and thus correspond to the pulsations of the jugular vein.

(10) The theory of the heart movement here advanced gives a satisfactory explanation of the arrangement of the cardiac musculature.

(11) Description of the method used in the examination of pathological hearts, in place of the cursory methods commonly employed (p. 24).

A METHOD OF INDICATING THE POSITION OF THE DIAPHRAGM AND ESTIMATING THE DEGREE OF VISCEROPTOSIS.

By ARTHUR KEITH, M.D.

THE manner in which the abdominal viscera are supported and maintained in position during life is a subject which has not received from anatomists the attention which its practical importance deserves. Amongst clinical men crude ideas prevail as to how the stomach, the liver, the kidneys, and the uterus are supported during life, and wholly unscientific methods employed to rectify their displacements. This undesirable state of affairs is due, in the first place, to the attention of the anatomists being too largely confined to the dead body, and in the second place, to the lack of an accurate method which can be applied to the living body for estimating the normal position of the abdominal viscera and the degree to which they may have fallen down from the normal. For clinical purposes it is useless to employ vertebræ as landmarks. The investigations of Dr Addison have done much to standardise [1] our knowledge of the position of the abdominal viscera. It was undoubtedly his methods that suggested to me the use of the xiphi-sternal line as a standard from which to measure the extent to which the viscera had fallen in cases of Glénard's disease.[2] A prolonged experience has convinced me that the xiphi-sternal line (fig. 1, *cc*) is of great clinical utility.

Even in fat people the depression at the junction of the meso-sternum with the xiphi-sternum, or the depression below the insertion of the seventh pair of cartilages—which for practical purposes may be regarded as the same—can be readily recognised. If a line be drawn horizontally across the body, through this point, it gives a standard in terms of which the upper limits of the abdominal viscera may be stated, not in vague intercostal spaces, but in centimetres. In X-ray work I have found a narrow strip of tin-foil applied along this line to serve as an excellent standard from which to take measurements.

The xiphi-sternal line as an index of the type of thorax.—In the normal

[1] C. Addison, "The Topographical Anatomy of the Abdominal Viscera in Man," *Journ. of Anat. and Physiol.*, vols. xxxiii., xxxiv., and xxxv.

[2] A. Keith, "Hunterian Lectures on the Anatomy and Nature of Glénard's Disease," *Lancet*, March 7 and 14, 1905.

thorax, in a position of rest, the xiphi-sternal line crosses the fifth pair of cartilages (fig. 1, *a*); if the thorax is emphysematous, it crosses below the cartilage (fig. 1 *a'*); if the ribs are depressed, as in the condition known as the *habitus phthisicus*, and in women who have worn tightly fitting corsets, it crosses above the fifth cartilage (fig. 1, *a''*). By stating the relationship of the xiphi-sternal line to the fifth pair of cartilages, definite information is given of the type of thorax. In three cases where eight cartilages reached the sternum on the right side, the xiphi-sternal line crossed, not the fifth pair of cartilages, but the sixth pair.

The following was the relationship of the xiphi-sternal line to the ribs

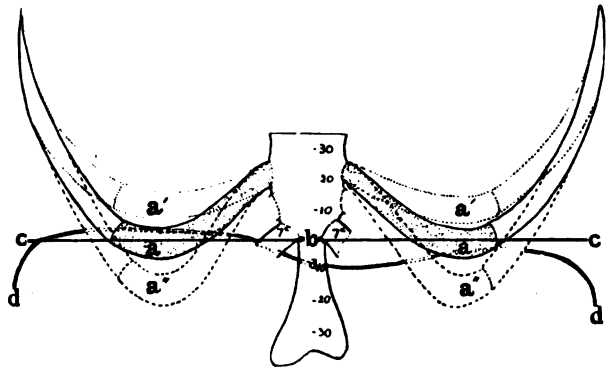


FIG. 1.—The xiphi-sternal line and its relationship to the fifth pair of costal cartilages.

a, the relationship of the line to the fifth pair of costal cartilages in a normal thorax; *a'*, its relationship in the emphysematous thorax; *a''*, its relationship in the so-called "phthisical thorax"; *b*, xiphi-sternal point; *c*, xiphi-sternal line; *d*, position of diaphragm (average of fifty dead subjects).

and intercostal spaces in twenty-nine adult male subjects, forty adult female subjects, and sixteen newly-born children:—

	Males.	Females.	Newly-born.
The line crossed—			
Fourth rib	0	1	0
„ space	2	22	2
Fifth rib	26	14	9
„ space	0	1	4
Sixth rib	1	2	1

The xiphi-sternal line as an index to the position of the diaphragm.—Taking the xiphi-sternal line as a standard, the position of the domes of the diaphragm are found to be extremely variable in position. To indicate the average level of the diaphragm, three points are taken on the line: (1) a *right*, vertically below the mid-point of the right clavicle; (2) a *median*,

at the xiphi-sternal point; (3) a *left*, in the left mid-clavicular line. The right dome should reach the level of the right point, the left dome lies from 5 to 10 mm. below the left point, the central tendon is 10 mm. below the median point. These three points can be used with great facility for clinical purposes. My observations on the living—chiefly on students—show that in the supine position the domes rise 8 to 10 mm. above the level they occupy in the upright posture. The respiratory excursions of the diaphragm above and below the line varies not only with the amplitude of the breadth taken, but also with the type of respiration and with training. In those whose movements are purely thoracic in type, the respiratory excursions of the diaphragmatic domes may be only 10 mm. above and 15 mm. below this line (a total excursion of 25 mm.), while in those with movements of the abdominal type, they may extend from 25 mm. above to 65 mm. below the line, a total excursion of 85 mm.

The xiphi-sternal line as an index for estimating the degree of visceroptosis.—Dr Franz Glénard,[1] to whose clinical labours we owe the recognition of the condition of visceroptosis, proposes to distinguish the low condition of the diaphragm described by me[2] under the name of *phrenoptose*, evidently regarding the condition as forming a variety of the forms of visceroptosis. On the other hand, I consider the level of the diaphragm as the true index of whether visceroptosis is present or not, and of the extent to which it is present, for there can be no ptosis of the viscera unless a corresponding sinking of the diaphragm be present. The diaphragm marks the upper level of the abdominal viscera; the extent to which they have sunk must be measured by the extent to which their upper level is depressed. In estimating the degree of ptosis, I take the three points in the xiphi-sternal line already mentioned—the right, middle, and left—and measure the distance to which the right dome, the central tendon, and left dome have sunk below these three points. If the right and left domes are 25 mm. or more below the right and left points, I regard the condition as one of visceroptosis. How far clinical experience will justify this artificial standard, time will show, but to make progress it is necessary, at least to commence with, to make an artificial standard.

In the following table I give the distance of the right dome, central tendon, and left dome above or below the right, middle, and left points of the xiphi-sternal line, as measured in 107 dissecting-room subjects, of both sexes, the majority of whom were over sixty years of age.

[1] *Bull. et Mem. de la Société Médicale des Hospitaux de Paris*, Feb. 22, 1906, p. 158.
[2] *Lancet*, March 7, 1903.

	Right Dome.	Central Tendon.	Left Dome.
+51–60 mm.	1	0	1
+41–50 „	1	0	1
+31–40 „	4	0	5
+21–30 „	15	1	9
+11–20 „	15	16	10
+ 1–10 „ xiphi-sternal line — 1–10 mm.	38	37	37
−11–20 „	9	22	11
−21–30 „	6	14	13
−31–40 „	8	11	9
−41–50 „	8	4	10
−51–60 „	2	2	1
−61–70 „	0	0	0

ON THE FORM OF THE CÆCUM.

By F. G. PARSONS, F.R.C.S.,
Lecturer on Anatomy at St Thomas's Hospital and the London School of Medicine for Women.

THE form of the cæcum has been dealt with in three important monographs,[1] so that our knowledge of it is considerable, but the work of Toldt has not been incorporated into our modern English text-books as fully as it, perhaps, deserves. My own observations were made before I had read



FIG. 1.—Abdominal viscera of a fœtus in the fifth month, seen from behind.
C., cæcum; K., right kidney, turned back.

Toldt's paper, and it was at once a pleasure and a disappointment to find how completely he had anticipated me in most of my conclusions.

There are, however, one or two points of minor interest on which he has not touched, as well as the records of seventy cases observed in the post-mortem room of St Thomas's Hospital.

Toldt shows that the cæcum first appears as a bud from the caudal end of the umbilical loop of the gut during the second month of intrauterine

[1] (1) Treves, *Hunterian Lectures*, 1875,—"The Anatomy of the Intestinal Canal and Peritoneum in Man."

(2) Struthers, "Varieties of the Appendix vermiformis, Cæcum, and Ileo-colic Valve in Man," *Ed. Med. Journ.*, 1893, p. 289.

(3) Toldt, "Die Formbildung des menschlichen Blind-darmes und die valvula Coli," *Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften*, Wien, 1894, Band ciii. p. 41.

life. This bud, as it grows, bends toward that part of the gut which is going to be the small intestine. Why this should be I do not know, but the same tendency can be seen in the cæca of most mammals, even when they are very short and when no evidence of an ileo-cæcal valve is present, and also in the double cæca of birds. In man the growth of the colon soon presses the cæcum against the liver to the left of the mid line, and by this pressure the cæcum and ileum become so closely approximated that their walls adhere for a certain distance, and so the formation of the lower cusp



FIG. 2.—Abdominal viscera of a fœtus in the sixth month, seen from behind. C., cæcum; H.F., hepatic flexure; Co., colon; I., ileum; K., right kidney, turned back; S.R., supra-renal.

of the ileo-cæcal valve is produced. During the next two months the cæcum traverses the abdomen from left to right, but has to pass downward as well, because of the obliquity of the liver.

When the right wall of the abdomen is reached the already curved cæcum has to take another direction as the colon goes on growing longer. It cannot grow upward or forward because of the liver, nor backward because of the kidney, and so it makes a sharp turn downward, and the junction with the appendix, which before had a downward direction, now points horizontally inward below the ileum (see fig. 1).

The cæcum has now gained the form of a ∽ when seen from in front, and the ileum joins it in its concavity.

The continued growth of the colon soon causes another bending, the hepatic flexure (fig. 2, H.F.), and the result of this is that the apex of the cæcum, where it joins the appendix, takes another bend of a quarter of a circle and now points upward, and the cæcum becomes an upright *b* when seen from in front.

By this time it has reached the lower pole of the right kidney, and the short limb of the *b*, which corresponds to the apex of the cæcum, is able to grow backward below the kidney (fig. 3), and so the apex and the conical



FIG. 3.—Abdominal viscera of a fœtus in the sixth month, seen from the right side and behind, to show the cæcum (C.) curving round the lower pole of the right kidney (K.). L., liver.

part of the cæcum leading to it (which it may perhaps be convenient to speak of as the "conus appendicis") now lies behind the ileum.

The cæcum has now attained the characteristic shape which I have never failed to find in a considerable number of full-term fœtuses, and my observations show me that it is during the formation of these sharp secondary bends that the upper segment of the valve is formed by a simple process of kinking.

It is probably owing to the fact that the cæcum bends backward that the anterior part of the ileo-cæcal orifice is rounded, while posteriorly it tails off into a sharp angle owing to the approximation of the two segments of the valve there. In other words, by the backward bend of the

cæcum, there is a tendency to stretch and open the front of the valve and to compress the back.

This *b*-shaped cæcum (see fig. 4), so well figured by Toldt and Struthers, and displayed by Hunter in the R.C.S. Museum, is, as I have said, almost always present in the later months of fœtal and in early extra-uterine life, and it will be convenient if we recognise in it, firstly, the cylindrical part near the valve; secondly, the tapering part, for which I propose the term conus appendicis; and thirdly, the appendix. It is important to distinguish carefully between the curvature of the cæcum and that of the appendix; the former takes place close to the junction with the ileum, and results in the formation of first the lower and then the upper cusp of the ileo-cæcal valve, by a process of, in the former instance, fusion, and in the latter,

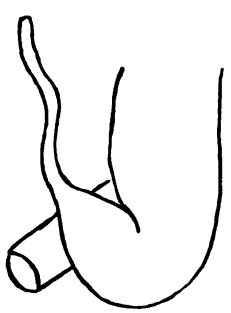


FIG. 4.

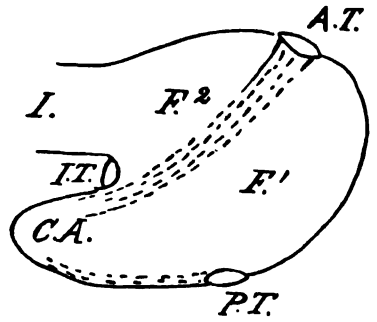


FIG. 5.—Diagrammatic horizontal section through the cæcum at birth, at the level of the ileo-cæcal valve.

kinking. The long appendix may be, and usually is, bent on itself in any direction, but these bendings are not permanent, have no effect upon the valve, and probably vary from time to time with the movements of the intestines.

During the first few years of life the lumen of the tube is very smooth and even, but about the fourth or fifth year distension by fæces and gas leads to sacculation, and the horizontal constrictions between the saccules usually correspond to vessels, which possibly determine their position.

Owing to the fact that the three tæniæ follow the bending of the cæcum, there is a larger space between the anterior and posterior tæniæ on the right side than there is between the anterior and left or the posterior and left tæniæ (see fig. 5, $F.^1$ $F.^2$). Moreover, the most dependent part of the cæcum corresponds to this larger space. For these two reasons a marked sacculation is produced by the internal pressure downward, forward, and to the right, between the anterior and posterior tæniæ, where the support is least. My specimens make me think that this usually

happens in the fourth or fifth year, though sometimes it never happens at all, possibly owing to greater strength or tone in the circular muscular fibres. A type of cæcum is now produced which shows the *b*-shaped curve complicated by a right anterior sacculation below, and beyond this stage the development of the cæcum often goes no further (see fig. 6).

In other cases the internal pressure causes sacculation between the anterior and left and posterior and left tæniæ as well, though these are usually much less marked than that just spoken of. There may be, too, a general distension of the cæcum which hides a good deal of its *b*-shaped curvature, and throws much of its original conical apex into the main cavity. The result is a type of cæcum with a large right anterior sacculation below and a bag-like form; but the apex of the cone ("conus

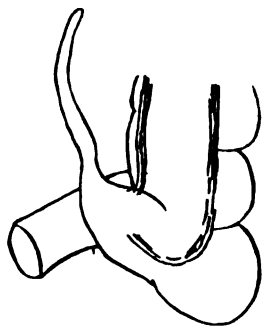


FIG. 6.



FIG. 7.

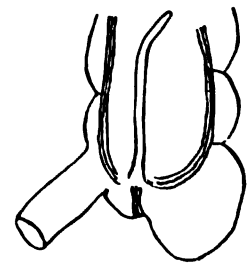


FIG. 8.

appendicis") is still evident behind and on the left (see fig. 7). If the process of general dilatation goes on, the conus appendicis may be altogether taken into the main cavity, and then the appendix seems to rise from the posterior and left part of the cæcum, behind and below the ileo-cæcal orifice. This is the typical cæcum of the text-books (see fig. 8); but it is not so common as one is led to believe, and the history of its formation may still be read in the curvature of the posterior tænia. The amount of distension which the cæcum undergoes from internal pressure seems to depend on the thickness and tone of its circular muscular coat, and the distensibility increases with age. Almost all the cæca on which this paper is based were seen by me on the day after death, and were blown up with the same bellows, and with, as nearly as possible, the same pressure, and I noticed that those coming from old people, especially old women, distended more than those from the young and middle-aged.

Toldt objects to conclusions based upon inflated and dried cæca, and I quite agree with him that the first examination and sketch or photograph

should always be made while the parts are moist. This I have been careful to do. I cannot, however, think that there is any real advantage in injecting with a fixing reagent rather than with air, because, in the living body, the cæcum is distended with gas, and its true shape is more likely to be restored with air pressure than with fluid. That this restoration of shape is very perfect I have convinced myself by drawing the naturally inflated cæcum before it was removed from the body, and afterwards comparing the sketch with the same cæcum removed and artificially inflated under a moderate pressure. I am also sure that the alteration brought about by drying the cæcum is very trivial. It is true that the appendix shrinks in calibre, though very little in length, and the segments of the

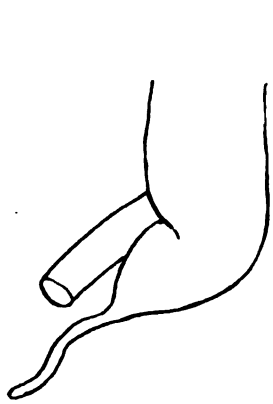


Fig. 9.



Fig. 10.

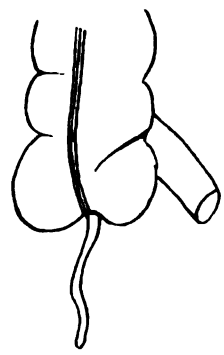


Fig. 11.

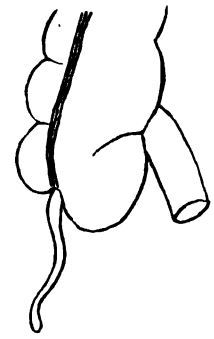


Fig. 12.

valve become sharp and paper-like, but the general shape is hardly at all affected as long as care is taken to suspend it in a proper position when drying, and to keep the appendix in the position it originally occupied. As might be expected, the degree of the *b*-shaped bending varied in different cases. In many of them the curve was less than a right angle, in some quite an obtuse angle (see fig. 9); but I noticed that in all these cases the appendix was very free, and, having a long meso-appendix or no meso-appendix at all, hung down into the pelvis. I believe that these cases are not instances of incomplete flexure unless they are accompanied by an abnormally small upper segment of the ileo-cæcal valve, but rather of a secondary straightening out after birth, owing to the appendix having taken up a pelvic position (I shall speak of them later as cases of "dropped cone"). One specimen, however, which was found in the dissecting-room of St Thomas's Hospital some years ago, is very interesting, because in it hardly any bending at all had occurred. The cæcum was a long and

perfect cone, ending in the appendix; and (see fig. 10) as it had never been pressed against the ileum in bending, no adhesion between the two parts had taken place; there was, therefore, no lower segment of the ileo-cæcal valve. There was also no kink where the concavity of the *b* should have been, and so no upper shelf-like fold of the valve was there. Clearly this specimen was one of an early embryonic type of cæcum before the formation of the valve, although it was taken from an elderly man. At the time, I thought the presence of the straight cæcum with the absence of any valve an interesting coincidence, but I now believe that the one was the direct cause of the other.

On inquiring at the infirmary where the patient died I could not learn that he had suffered the least inconvenience from the absence of a valve, and I am inclined to doubt whether it is a structure of any great physiological importance. This is a type of straight cæcum in which no flexure has occurred, and is the only undoubted one of its kind which I have ever seen. In the secondarily straightened-out cæca in which the cone has dropped there is usually some bending backward, even if the lateral curvature is effaced; and so the anterior tænia runs backward below the middle of the lower end of the bag, and the internal pressure often makes as large a sacculation on the left side of it as on the right. This, I believe, is the explanation of those cæca in which the two anterior sacculations are of equal size (see fig. 11), and also of the two specimens I have come across in which the left is larger than the right (see fig. 12), because in all these cases the conus appendicis or opening of the appendix is a little behind the bottom of the bag, and not behind and to the left; while in those cases in which the right sacculation is large, the root of the appendix is always well to the left behind the ileum.

This point may perhaps be of some slight use to surgeons in cases in which the appendix is hard to find.

In the following list my seventy specimens are arranged according to age, but I have not included the conical cæcum without a valve, because it was probably one out of many thousands.

1. 1 day, ♂. Perfect *b* (fig. 4).
2. 2 days, ♂. „ „
3. 2 weeks, ♂. „ „
4. 1 month, ♂. Dropped cone (fig. 9).
5. 2 months, ♂. „ „
6. 3 „ ♂. Perfect *b* (fig. 4).
7. 6 „ ♂. „ „
8. 6 „ ♀. „ „

9.	6 months,	♂.	Perfect *b* (fig. 4)
10.	7 „	♀.	„ „
11.	7 „	♂.	Dropped cone (fig. 9).
12.	7 „	♂.	*b* „
13.	9 „	♀.	Dropped cone (nearly vertical).
14.	11 „	♂.	*b* (fig 4).
15.	13 „	♂.	„ „
16.	16 „	♂.	„ (slight right sacculation) (fig. 6).
17.	21 „	♀.	„ (fig. 4).
18.	2 years,	♀.	Dropped cone (fig. 9).
19.	2½ „	♀.	*b* (fig. 4).
20.	2½ „	♀.	Dropped cone (fig. 9).
21.	4 „	♂.	*b* (slight right sacculation) (fig. 6).
22.	5 „	♂.	Conus appendicis. Slight right sacculation (fig. 7).
23.	5 „	♂.	„ „ „ „
24	6 „	♂.	„ „ „ „
25	6 „	♀.	*b* Right sacculation (fig. 6).
26.	6 „	♀.	„ (fig. 4).
27.	6 „	♀.	C. append. Right sacculation (fig 7).
28.	10 „	♂.	*b* „ „
29.	11 „	♀.	„ (fig. 4).
30	12 „	♂.	C. append. Right sacculation (fig. 7).
31.	16 „	♂.	„ „ „
32.	18 „	♀.	Dropped cone (fig. 9).
33.	19 „	♂.	No c. append. Large right sacculation (fig. 8).
34.	21 „	♂.	*b* Right sacculation (fig. 6).
35.	23 „	♀.	„ „ „
36.	25 „	♂.	C. append. Left sacculation (fig. 12).
37.	28 „	♂.	No c. append. Right sacculation (fig. 8)
38.	28 „	♂	„ „ „
39.	28 „	♂.	C. append. „ (fig. 7).
40	30 „	♂.	No c. append. „ (fig. 8).
41.	30 „	♂.	„ „ „
42.	32 „	♂.	C. append. Right and left sacculations (fig. 11).
43.	34 „	♀.	*b* (fig. 4).
44.	39 „	♀.	„ „
45.	42 „	♀.	No c. append. Right sacculation (fig. 8).
46.	42 „	♂.	C. append. „ (fig. 7).
47.	43 „	♂.	*b* „ (fig. 6).
48.	44 „	♂.	No c. append. „ (fig. 8).
49.	45 „	♂.	„ „ „

50. 46 years, ♂. No c. append. Right sacculation (fig. 8).
51. 48 „ ♂. *b* „ (fig. 6).
52. 50 „ ♂. C. append. „ (fig. 7).
53. 52 „ ♂. *b* (fig. 4).
54. 55 „ ♂. C. append. Right sacculation (fig. 7).
55. 57 „ ♀. „ Right and left sacculations (fig. 11).
56. 58 „ ♀. *b* (fig. 4).
57. 58 „ ♂. „ Right sacculation (fig. 6).
58. 59 „ ♂. „ (fig. 4).
59. 60 „ ♂. „ „
60. 60 „ ♂. „ „
61. 63 „ ♂. No c. append. Right and left sacculations (fig. 11).
62. 64 „ ♂. C. append. Right sacculation (fig. 7).
63. 65 „ ♂. No c. append. Left sacculation (fig. 12).
64. 67 „ ♂. *b* Right sacculation (fig. 6).
65. 71 „ ♂. „ „ „
66. 76 „ ♀. C. append. „ (fig. 7)
67. 76 „ ♀. No c. append. Great uniform distension (fig. 8).
68. 79 „ ♂. *b* (fig. 4).
69. 82 „ ♂. C. append. Right and left sacculations (fig. 11).
70. 84 „ ♂. „ „ „ „

From this list it will be seen that the *b*-shaped type (fig. 4) without any marked sacculation is commonest in young subjects, but often persists throughout life. It is present in 31 per cent. of all ages, but if adults over twenty years are only taken, in 22 per cent.

The *b*-shaped cæcum, with or without a right sacculation below, occurs in 58 per cent. of all ages, and in 40 per cent. over twenty.

The type in which the conus appendicis has dropped secondarily is seldom seen in adults, because it is masked by later distension. I have not met with it in subjects over twenty years of age. In five out of the seventy specimens the right and left anterior sacculations were either quite equal or nearly equal in size (fig. 11), while in two cases the left anterior sacculation was distinctly larger than the right (fig. 12).

It is interesting to notice that the type of cæcum shown in fig. 8 (the normal type of our text-books) only occurred in ten out of my seventy cases. Of course, allowance must be made for the personal equation of the observer, but when this is done, it can be very little commoner than any one of the types shown in figs. 4, 6, and 7, even in adults over twenty, while under twenty it is very rare. The kind of cæcum most likely to be found in an adult is one of the transitional types shown in figs. 6 and 7.

In connection with the cæcum I should like to mention a condition of the peritoneum to which my attention was called by a surgeon who noticed it during an operation. He said that an apron-like fold of peritoneum hung down from the ileum for some inches before the latter joined the cæcum. In my seventy cases I have twice seen this fold, and have satisfied myself that it is the ileo-appendicular or bloodless fold, greatly enlarged, and hanging down from the ileum before turning upward and backward to the appendix. It thus consists, like the great omentum, of four layers of peritoneum.

THE MICROSCOPICAL ANATOMY OF THE GENITAL TRACT IN THE RAT KANGAROO (FEMALE).

By D. BERRY HART, M.D., F.R.C.P.E., F.R.S.E., *Lecturer on Midwifery, Edinburgh; Carnegie Research Fellow.*

I MAY briefly state that in this species the female genital tract consists of two ovaries, two tubes, two cornua, and a complicated vaginal tract. This last is made up of two lateral canals, arching up and meeting one another between bladder and cornua, while below they open into the urinogenital sinus. A central vaginal pouch, communicating above with

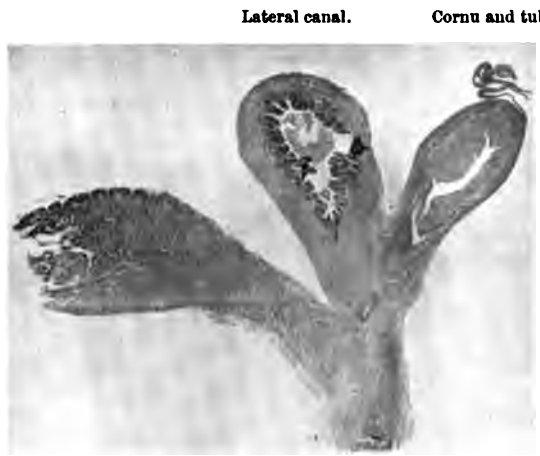


FIG. 1.—Rat kangaroo (female genital tract). ⅔. Shows ureter and corner of bladder on section, as well as central pouch, cornu, and tube. ⅔.

the lateral canals, but blind below, lies centrally, and is thus bounded on each side by the lateral canals right and left (see fig. 1).

The morphology of this tract will be best considered afterwards. The microscopical anatomy was investigated on a specimen of the rat kangaroo, and as I obtained it alive I was enabled to preserve the genital organs perfectly. In each organ serial sections were cut with the Cambridge microtome, and the stains used were logwood and eosin. The sections thus obtained amounted to several hundreds.

The Ovary.—With one exception the structure of the ovary closely resembled that of the human female.

The outer surface of the ovary was covered with low columnar epithelium—the germ epithelium—except at the hilum ovarii, where the Fallopian tube was attached by its fimbriated end. Below the germ epithelium is a layer of connective tissue, made up mainly of spindle cells, with their long axes parallel to the long axis of the organ, and forming



FIG. 2.—Tube and ovary, showing duct of Müllerian origin in ovary. $\frac{6}{1}$.

a distinctly marked-off tunica albuginea. From it passed radiating fibres into the general mass of the ovary.

The general substance of the ovary is made up of connective tissue, Graafian follicles, and corpora lutea cells.

The *general connective tissue* is of a round-celled type, but there were also cells of a more epithelial type adjoining a large corpus luteum.

Graafian Follicles.—These are present in fair amount, but not in the abundance one sees in the rabbit for instance. There is the same grouping as in the human female, of smaller follicles at the periphery, larger ones deeper.

In the larger single Graafian follicles we have externally a well-marked tunic of spindle connective tissue lying between the membrana granulosa inside and the general connective tissue outside.

The membrana granulosa and discus proligerus are well marked and are made up of rounded cells with large, deeply stained nuclei, quite different in appearance from the general connective tissue of the ovary. In the deep layer of the membrana granulosa the cells are distinctly columnar, while above they are rounded. Their appearance is markedly of an epithelial type. Within the discus proligerus lies the ovum, with its zona pellucida, yelk, germinal vesicle, and germinal spot. The Graafian follicles of a medium size all have the same structure practically. The youngest ova are in groups near the surface, have liquor folliculi round them, but no



FIG. 3.—Duct in ovary of Müllerian origin, under higher power. $\frac{2}{1}$°.

membrana granulosa. The tunic is a single layer of spindle-celled connective tissue. Several ova may be enclosed in the one tunic, but one ovum alone is usually present.

A very large and organised corpus luteum is present, with a peculiar structure in connection with it, to be considered now.

Unusual tubular structure in the Ovary.—In the centre of the large corpus luteum and also at its side there is present an arrangement of tubules made up of one branching and larger system, with two to three tubules at the side. This is, of course, as seen on section. The cavities of these are lined with epithelium, but there is no evidence of secretion in the cavity. The wall of this tubular arrangement is made up of connective tissue (spindle-celled) and unstriped muscular fibre embedded in a homogeneous

basis, staining with eosin. All this is surrounded with corpus luteum cells in most of its periphery, and outside the whole is a capsule of unstriped muscle (circular fibres and longitudinal) (figs. 2 and 3). The question has now to be considered as to the nature of this structure. It is impossible to say in this instance whether it is normal or abnormal for this species of animal. Analogous structures have not been described normally in connection with the ovary of any mammal, so far as I am aware.

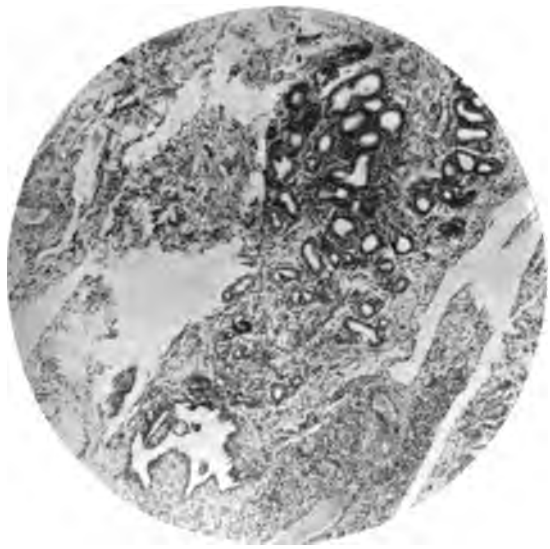


FIG. 4.—Parovarium in broad ligament, with large section of duct of ovary at left lower angle. $\frac{5}{1}^{0}$.

The possibilities of its nature are as follows:

1. *Corpus luteum cyst.*
2. *Papillomatous cyst.*
3. *Wolffian duct.*
4. *Müllerian duct.*

(1 *and* 2) *Corpus luteum Cyst.*—It is unlikely that this is its nature. It has none of the characteristics of that form of cyst, nor of a papillomatous one, although its relation to the corpus luteum cells is difficult to explain. It is possible, however, that originally a Graafian follicle may have been near the tubules or surrounded by them, had ripened, and thus formed its corpus luteum round them.

(3) At one time I thought the structure was derived from the Wolffian duct, as when traced on serial sections to the broad ligament it came

suddenly into apparent continuity with what looked like epoophoritic tubules (parovarium). The Wolffian duct has not, however, such a branching structure, and I am inclined to withdraw my original opinion after a more extended examination of this specimen (fig. 4).

(4) It seems to me most likely that these branching structures are derived from the developing Müllerian duct, and are thus really part of the Müllerian duct in an abnormal position. The reasons that may be advanced in support of this opinion are as follows:—

(*a*) The aberrant tube is at the ovarian hilum and close to the normal Fallopian tube.

(*b*) Diverticula of the aberrant tube are found near the periphery of the ovary, but there are none opening on the surface of the ovary.

(*c*) The structure of the aberrant tube is quite like that of the actual tube, but less developed.

(*d*) Development supports this view markedly, especially if we consider with Waldeyer that the Müllerian duct develops as a groove in the germinal epithelium, and becomes a tube afterwards, its epithelium thus being derived from the germ epithelium.

(*e*) A unique case has been recorded in the human female by Russell of the Johns Hopkins Hospital, where the right ovary of a patient who had been submitted to ovariotomy for a left ovarian adeno-sarcoma had in its substance mucous membrane and interglandular connective tissue like the normal uterine mucosa, and communicating with the surface of the ovary. There was no doubt this was due to an aberrant development of the Müllerian duct. This observation of Russell has an important bearing on our specimen, but in our case the structure is arranged more like a tubal than a uterine one. In Russell's case the mucous membrane in the ovary has glands, and is quite like uterine mucous membrane.

One cannot dogmatise on the nature of the structure, but the evidence is strong as to its Müllerian origin at any rate, with probably corpus luteum cells intruded between its muscular coat and the mucous membrane.

The *Fallopian tube* from within out has well-marked folded mucous membrane, with columnar epithelium on the free surface, resting on round-celled connective tissue. Outside this we find unstriped muscular fibre, mainly circular, and finally a layer of connective tissue, and then the peritoneal coat.

The *cornua*, two in number, are lined with a well-formed thick mucous membrane, formed of closely packed tortuous glands, with connective tissue between.

The free surface is lined with well-formed columnar epithelium, containing a well-marked nucleus. The glands are very abundant, tortuous,

and lined with columnar epithelium. The interglandular connective tissue has a homogeneous ground substance, universally stained, with round and spindle-celled connective-tissue cells. The spindle cells in many instances wholly or partially surround the periphery of the gland sections, forming an appearance like a boundary membrane, but this condition hardly exists at the free surface. The muscular coat is much less thick than the mucous membrane, and has a simple arrangement of its unstriped muscular coat. There are bundles of circular fibres, and outside these a thinner layer of



FIG. 5.—Lining of lateral canal, with cell debris in lumen, and part of wall. $\frac{1}{12}$.

longitudinal muscle, with individual cells well seen. As one approaches the fundus, the circular muscular coat disappears and only longitudinal fibres are present. The anterior cornual wall is much better developed than the rest of the cornu. Outside the muscular coat lies the peritoneum with a well-marked layer of connective tissue separating them (fig. 1).

We now take up the *lateral and central canals.*

The *lateral canals* are two in number and have a characteristic structure. Each is lined with many layers of squamous epithelium on narrow papillæ of connective tissue (figs. 5, 6, and 7). The connective tissue is sparingly developed, but the muscular coat outside is thick and very well marked. The muscular bundles are mainly circular and longi-

tudinal (middle), the circular being the thicker. There are also indications of fibres running obliquely.

In the epithelial layer the deep cells stain more markedly, are oval in shape, and have large nuclei. The superficial cells have smaller nuclei and gradually become more squamous in appearance (fig. 6).

In the lumen of the canal (fig. 7) is a considerable amount of cell debris, mainly degenerated shed squamous cells. The whole structure of the lateral canals is characteristically vaginal.

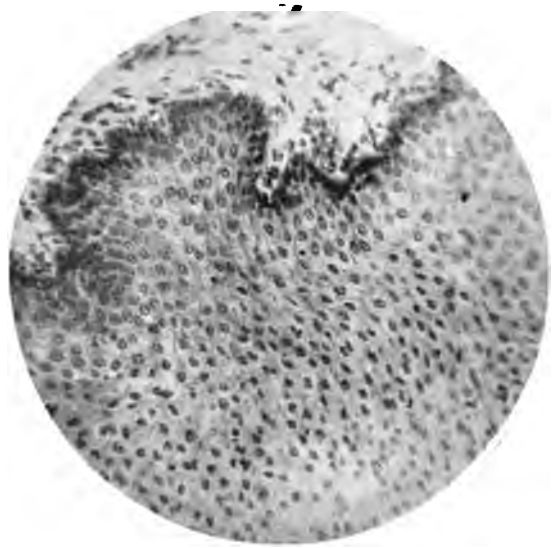


FIG. 6.—Epithelium of lining of lateral canal: the deep layer is upper in the photograph, and the free surface is not shown. $\frac{200}{1}$.

The *central canal* or *pouch* lies between the lateral canals, and on T.S. of the genital cord we see this very distinctly, the urethra lying in front, and the two lateral canals one on each side of the central one, whose mucous cavity may be described as X-shaped when cut in this direction. It is worthy of note that there is a thin sphincter surrounding these structures (fig. 7).

The "central canal" is lined with single-layered columnar epithelium on papillæ of connective tissue, forming in this way wide glandular recesses, with occasional narrow ones, at the sides usually. The epithelial cells are long and somewhat narrow, with marked nuclei. They resemble the cells of the cervical mucous membrane in the human female. Both the connective tissue and muscular coats are only slightly developed, and thus the

epithelial connective tissue and muscular coats are feebly represented as compared with the lateral canals. The muscular coat proper of the central canal surrounds it and the urethra (fig. 7).

The *urethra* is well marked, has a mucous lining of many-layered cells and well-developed connective tissue; muscular coats, longitudinal outer, circular middle, with bundles also in the connective tissue.

In the *external genitals* there was nothing in the microscopical sections

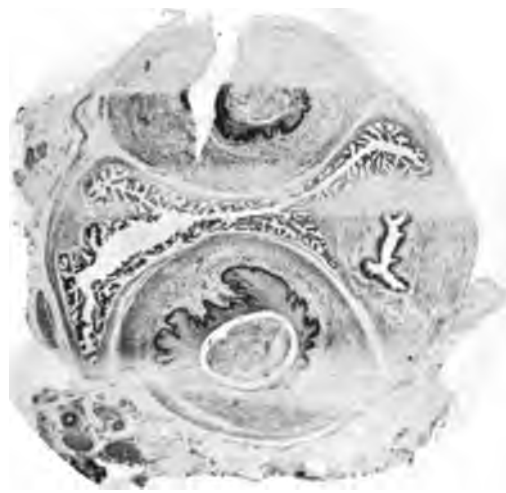


FIG. 7.—Genital cord in rat kangaroo, showing lateral canals, central canal, and urethra. $\frac{1}{1}^{0}$.

of any special note. Glandular secreting elements were present, and there was a long tapering clitoris. There were distinct sebaceous glands present, with ducts lined by a single layer of low columnar epithelium.

The genital tract in this animal is bicornuous in its uterine segment, and has the peculiar arrangement in the vaginal segment already described. We are justified in ascribing the bicornuous condition to a non-coalescence of the original Müllerian ducts, the usual developmental explanation applied to the higher mammals. We have a more difficult task in attempting to explain the morphological nature of the vaginal segments.

Nature of the Vaginal Segments.—When the central pouch and lateral canals, all three, communicate with the urinogenital sinus, the arrangement

has been described as a trifid vagina. This, however, does not help us to understand the condition, and does not hold good when, as in the specimens examined, the central vaginal segment is closed below.

The *lateral canals* have an undoubted vaginal structure; their mucous lining is multiple squamous epithelium, like that of the human female vagina, and the main question is whether we are to hold them as derived from the Müllerian ducts or not. We leave this point at present, as it is intimately bound up with the question of the nature of the "central pouch" or "canal."

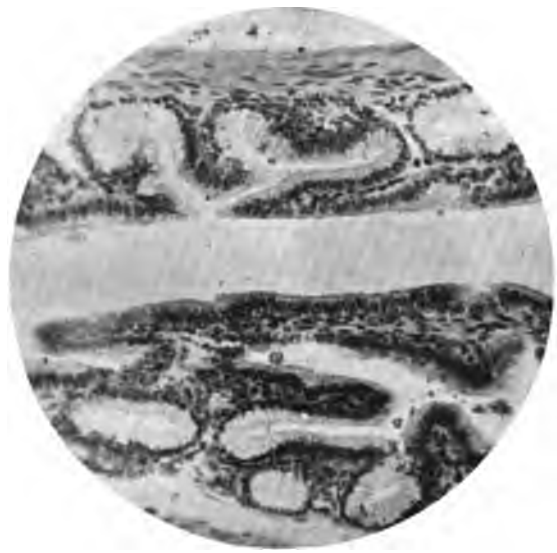


Fig. 8.—Arrangement of epithelium in central canal. $\frac{2\,0\,0}{1}$.

In its structure the central canal differs from the lateral canals, as it is lined with columnar epithelium in single layer and has a feebler development of wall. When communicating, as it does in some instances, with the urinogenital sinus below, one is tempted to consider it as almost a prolongation of the cervix.

I have in a previous paper endeavoured to show that the human vagina is not solely derived from the ducts of Müller, but that in its lower one-third it is urinogenital sinus *plus* Wolffian ducts, and that the hymen is a product of the lower ends of the Wolffian ducts. It seems to me more likely that the lateral canals in the kangaroo are really the persistent Wolffian ducts, and that the central canal is vaginal, not cervical, and a product of the Müllerian ducts. The lateral position and structure of the lateral canals

are in favour of this view. We do not know what germ layer the Wolffian ducts are derived from in the kangaroo, but it is probably, as in the human embryo, from the ectoderm, the layer which gives, *inter alia*, the skin-like multiple cells. It may be urged that the central canal has not this epithelial arrangement, but I have to point out that it has been shown by Tourneux and others, including the author, that the first lining of the vagina is single-layered, and comes afterwards to be replaced by the squamous multiple layers, and this I have traced in the human fœtus to proliferation from the lower ends of the Wolffian ducts.

The fact that the central canal is cut off in this specimen of kangaroo from the lower ends of the Wolffian ducts may have excluded it from an analogous relining from below, but I must also point out that there is no developmental support of this, as in the human fœtus.

In the sections of the kangaroo examined and in those described by other authors (fig. 1) the ureter is seen, but not anything to be considered as a rudimentary Wolffian duct. This is, as I have suggested, represented in the lateral canals. What I believe to be the ureter has the multiple lining of well-formed elongated epidermal cells we usually find in this tube, and this lining is the same as that found in the corner of the bladder lower down, near where the ureter enters. If it be considered as the Wolffian duct, then there is the insuperable difficulty that there would be no ureter represented in the sections.

The view I urge then is, that in the kangaroo genital tract we have a persistence and non-coalescence of the ducts blended to form the vagina in higher mammals, viz. the Wolffian (lateral canals) and Müllerian (central). Thus, while apparently a complicated structure, it is really a persistence and non-coalescence of the primitive Wolffian and Müllerian canals.

In the developing human embryo at the sixth week we have, as shown in Keibel's well-known models, and confirmed by a specimen in my possession, an analogous arrangement. There the Müllerian ducts end blindly in the Müllerian eminence (just as the central pouch of the kangaroo is closed below), while the Wolffian ducts open below into the urinogenital sinus, an arrangement exactly the same as the lower relations of the lateral canals to the kangaroo urinogenital sinus.

The question of what the overarching part of the lateral canals represents has not been considered by anyone so far as I know, but, on the view of the lateral canals given here, it would be equivalent to the broad ligament segment of the Wolffian duct. Sufficient is not known of its early development to explain the union above of the lateral canals in the arching portion.

ON THE RÔLE OF THE DEVELOPING EPIDERMIS IN FORMING SHEATHS AND LUMINA TO ORGANS, ILLUSTRATED SPECIALLY IN THE DEVELOPMENT OF THE PREPUCE AND URETHRA.

By D. BERRY HART, M.D., F.R.C.P.E. & F.R.S.E.,
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BOTH the clitoris and penis are protected by a sheath or prepuce of skin, that of the penis being more complete than in the case of the clitoris, where it is deficient on its inferior aspect. The question arises as to how this prepuce is formed, and I purpose considering its method of formation on the basis of microscopical sections of the human preputium penis at the second and a half month and fourth and a half month; and of the preputium clitoridis at the fourth and seventh month respectively.

As a rule, the preputium penis is well developed at full time, completely covering the glans and usually projecting beyond its tip, while it can in most infants be drawn back so as to uncover it. The same holds good for the clitoris, but opportunities for examining its conditions are not so frequent as in the male child. Occasionally, and more especially in the male child, the prepuce cannot be so drawn back, and is then said to be adherent.

The usual description of the development of the prepuce is that a fold of skin grows forward and covers the glans, and this growth is generally considered to be of the nature of a free fold, so that the inner surfaces of the prepuce and that of the glans are not normally blended.

If, however, we examine sections of the developing glans and prepuce, we find that the development of the prepuce is more complex than thus stated. In a coronal section of the prepuce and clitoris at the fourth month the glans is seen to be bounded on its outer surface by a horseshoe arrangement which is made up of the future preputial space filled with epidermal cells. The outer surface of the glans is covered with deeply stained columnar cells of a narrow type, while the inner surface of the prepuce is also lined with the more highly stained cells which lie at the deep boundary of the epidermis. The important point is that the preputial space does not as yet exist, but is represented by epidermal cells joining the glans and preputial cell boundaries already mentioned.

If now we examine sagittal sections in a two and a half months male fœtus we see an earlier stage of preputial development. Covering the exposed glans

is a thick epidermal layer continuous with that of the body of the penis, while on the dorsum the epidermis has begun to dip down at the glans base, as if a dorsal fold were growing downwards and forwards (figs. 1 and 2). On the inferior aspect a very slight indication of a similar process is shown; and as the same is going on laterally, it is evidently a dipping downwards and forwards, especially of the epidermis of the body of the penis all round the glans. I have not an intermediate stage between this and the fuller

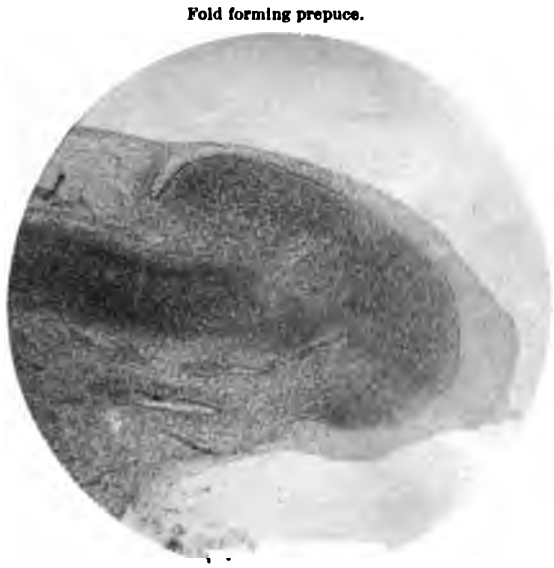


FIG. 1.—Sagittal lateral section of penis in two and a half months fœtus, showing folding beginning to form prepuce above.

development a few months later, but this may be inferred with some safety from the early state.

If we look at the sagittal mesial section we see a similar arrangement (fig. 3); but as the urethral aperture is shown, the epidermis is seen passing into it and continuous with the covering of the free surface of the organ. The special point then is that the prepuce is not at this stage unattached to the glans, but forms continuous tissue with it.

In the clitoris and prepuce of the seventh months fœtus an arrangement similar to that of the fourth month is present, but the central cells in the epidermal ones joining the glans and inner preputial surface are distinctly flattened, *i.e.* approach to the condition of the superficial shedding cells of the ordinary surface epidermis (fig. 4).

The prepuce does not, therefore, grow forward as a free unattached sheath, but develops somewhat as follows.

We begin with the two and a half months male, the earliest specimen examined. Here the glans has no prepuce, but is covered with a thick epidermal layer. At the glans root the epidermis dips down solidly and then grows forwards over the glans, the fold becoming inverted, *so that what was superficial is now deep, facing the glans surface.* The glans and the developing fold are blended and continuous as a tissue, and the future preputial space is thus filled with epidermal cells, the central ones corresponding to the superficial epidermal layers. This gives a fuller and more accurate account than one I had previously published, where I drew attention to the continuity of glans and preputial structure, but spoke less accurately of the epidermis passing in and back from the apex and mapping out the glans, without attaching sufficient importance to the important forward growth of solid folds from the glans base. We thus get a stage later in fœtal development, where—



FIG. 2. —Fold beginning to form prepuce.

1. The prepuce has formed.

2. The folds have not coalesced at the apex, a projecting epidermic plug preventing this.

3. There is no separability of prepuce from glans, but epidermal cells, unbroken, join them.

The question now arises as to how the prepuce becomes separable and free from the glans, as it does in the later months of fœtal life, apparently at or near full time.

The explanation is probably as follows. The surface epidermis is, when fully developed in the fœtus, made up of multiple cells, with an active deep single layer of more columnar and deeply-staining cells. As one examines the cells nearer the surface we see them gradually assuming the transparent ordinary epidermal type, the nucleus becoming smaller and the cell substance less, until we get the flattened epidermal squames of the free



FIG. 3.—Sagittal mesial section of penis in two and a half months fœtus, showing formation of prepuce and tunnelling of glans to form its urethra.

surface. The epidermis has a power of desquamating at its free surface, and we get in this the explanation of the ultimate separation of prepuce and glans, so that the former becomes movable and can be drawn back, or the latter can project during erection. Thus in the seventh month fœtus the central cells in the horseshoe arrangement are derived from the superficial epidermis and can be seen to have the flattened condition of superficial epidermal squames, *i.e.* are in the condition of desquamating cells. It is this that frees the prepuce from the glans and gives its normal separable condition—"a desquamation of the central cells in the epidermal layer joining the inner surface of the prepuce and the outer surface of the glans."

We thus get the explanation of the power of the epidermis in forming lumina or bringing about mobility in apposed surfaces formed by its solid indipping, as it is evident that when epidermis dips in or grows in to the mesoblast so as to form a solid infolding, the superficial epidermal cells thus become central, and their ultimate desquamation will make lumina or movable folds, as the case may be. The deep epidermal layer is evidently the active one in the indipping, as it stains deeply and has a larger nucleus than the more superficial cells. It follows from this that the so-called



FIG. 4.—Preputial space filled with epidermis cells in seven months fœtus. Note central ones more squamous. $\frac{2}{1}\frac{0}{0}$.

adherent prepuce found in young children is really due to deficient breaking down of the preputial epidermic plug, and not to pathological adhesions, *i.e.* is due to a delay in a developmental process.

The Formation of the Urethra in the Male.

The question I wish to discuss here is how the open part of the urethra in the early embryo (11–13 mm. of Nagel) has the urethral canal formed and the glans perforated to form the continuous tube of the male. In the female this part remains open and the glans imperforate, but the cause of this, as well as that of the opposite change in the male, is undetermined. In the 11–13 mm. embryo the condition in the urethral area below that

part of the urethra derived from the urinogenital sinus is shown in Nagel's diagram.

In a male embryo of an age between the second and third month I was fortunate enough, in a sufficient number of sagittal mesial sections, to be able to study the process of "closure," and now consider—

1. *The perforation of the glans penis.*
2. *The closure of the inferior portion of the urethra below that derived from the urinogenital sinus.*



FIG. 5.—Shows closure of inferior aspect of urethra in two and a half months fœtus.

1. *The Perforation of the Glans penis.*

The glans clitoridis is imperforate, but in the male the glans becomes tunnelled by the epidermis at the apex passing in and back, and thus forming a solid plug, which by central desquamation forms a lumen, as already described in the case of the prepuce. One can see the deep epidermal cell layer on the glans surface continuous with that in the urethra and the canal filled with epidermal cells, often in the form of cell nests. This tunnelling passes beyond the glans through the tissue corresponding to the future vestibule in the female, but an aperture is left immediately behind the frænum, and also somewhat further back. The way in which these appear to be closed is interesting.

The superficial epidermis between these two apertures grows in two directions—superficially, and also with its deep layers streaming in at the apertures, *i.e.* passing in deeply. Fig. 5 shows well the deep margins of the opening brought together as it were by means of the deep active epidermal cell layer. Thus the epidermal layer does three things in closing the urethra below:—

1. It proliferates in at the apertures solidly, carrying the superficial cells in its centre.

2. The deep contiguous active cells unite to close any aperture; and

3. The superficial epidermis proliferates over the closed apertures so as to make a surface.

Finally, the central cells in the blocked urethra break down and form the lumen.

Hypospadias, in its varying degrees, results from the failure of this closure.

THE PRESENCE OF A FALSE ACETABULUM IN A SPECIES OF BANDICOOT. By Professor BRIDGE.

WHILE recently examining the skeleton of an adult specimen of a common Australian bandicoot (*Perameles*, sp.), it was noticed that the right half of the pelvic girdle was furnished with a well-developed secondary or "false" acetabulum for the reception of the head of the femur; and, as the specimen presented several points of general as well as of surgical interest, it seemed desirable to publish a short descriptive note.

The false acetabulum was situated dorsad to, and somewhat in front of, the normal acetabulum, the anterior half of the former being in front of the anterior wall of the latter. In the dried skeleton (fig. 1) the dorsal and posterior limits of the false acetabulum (*f.a.*) were strongly defined by a prominent crescentic or semicircular ridge of bone, but the ventral and posterior boundaries, although sufficiently obvious, were less strongly marked, and in part, that is on the ventral side, were formed by the prominent dorsal rim of the true acetabulum (*n.a.*). In short, the false acetabulum, if somewhat shallower and perhaps a trifle larger than the normal acetabulum in the dried condition, was, nevertheless, a perfectly well-defined socket. When it first came under observation the skeleton had been stripped of the flesh and dried; but after a prolonged soaking of the girdle in water it was apparent that the false acetabulum (fig. 2, *f.a.*) was considerably deeper than in the dried state, owing to the fact that the limiting bony rim was encircled by a thick ridge of very dense fibrous tissue (*s.c.l.*) which, through the absorption of water, had regained its normal thickness, and in its relation to the socket was strongly suggestive of a secondary cotyloid ligament. Under these conditions there was but little apparent difference between the false and the true acetabulum either in size or depth or in appearance.

The greater part of the false acetabulum was formed by the gluteal surface of the ilium near the junction of that bone with the ischium. As a rule, in Mammals the vertical dorsal portion of the A-shaped suture between the ilium, ischium, and pubis bisects the dorsal half of the true acetabulum; and if this be so in *Perameles*, it will follow that at least the anterior three-fourths of the false acetabulum will be anteriorly placed with regard to a dorsal prolongation of this suture, and therefore will be

formed by the ilium, the adjacent portion of the ischium contributing the remainder. From the position of the false acetabulum dorsal to the normal and more laterally-situated acetabulum, it may also be noted that while the latter looks outward and also a little downward, the former is directed obliquely outward and upward, after a fashion which recalls the normal acetabulum in many, if not in all, Cheiroptera.

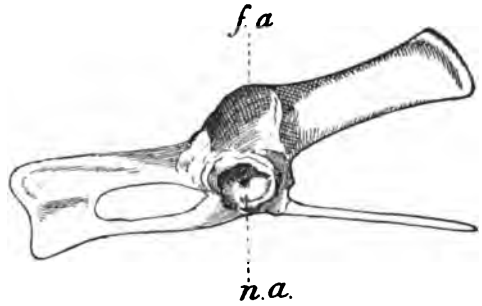


FIG. 1.

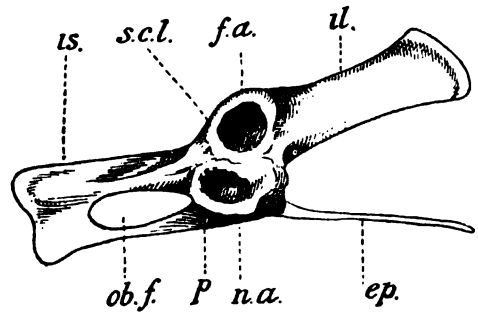


FIG. 2.

FIG. 1.—Lateral view of the right half of the pelvic girdle in the dried condition. FIG. 2.—Similar view, showing the two acetabula before drying. *ep.*, epipubic bone; *f.a.*, false acetabulum; *il.*, ilium; *is.*, ischium; *n.a.*, normal or true acetabulum; *ob.f.*, obturator foramen; *p.*, pubis; *s.c.l.*, secondary cotyloid ligament.

That the head of the femur articulated with the false acetabulum as with a true acetabulum there can be no doubt whatever, for this was its condition when the specimen was first examined; but apart from the encircling ridge of fibrous tissue, which probably acted as a secondary or false cotyloid ligament in retaining the head of the femur in position, no other connecting ligaments were seen, and, if any such had existed, they were removed when the flesh was first dissected away in the preparation of the skeleton.

There can be no doubt that the false acetabulum was the result of an upward or dorsal dislocation of the head of the femur, which, if we bear in mind the time necessarily required for the formation of the new and apparently functional socket, probably took place some considerable time prior to the death of the animal. The displaced head of the femur during its subsequent movements in contact with the surfaces of the ilium and ischium dorsad to the empty normal acetabulum would excite an inflammatory condition in these bones, and eventually lead to the growth of an encircling rim of osseous and fibrous tissue round the head of the femur, which ultimately formed the boundary of the false acetabulum.

The formation of a false acetabulum as a sequel to an unreduced dislocation of the head of the femur is known to occur in Man under similar circumstances, and the position of the new socket may be either dorsad or outwards as in the specimen of *Perameles*, or "thyroid" or inwards; that is, ventral, when, as in a case cited by Gould and Warren, the growth of new bone resulted in the formation of a false acetabulum occupying the position of the thyroid or obturator foramen. But, so far as I have been able to ascertain, in none of the recorded instances does the false socket so closely resemble a normal acetabulum, or offer so interesting an illustration of recuperative capacity, as is the case with the *Perameles*.

It is interesting to note that, subsequent to the dislocation and the acquisition of a new functional acetabulum, the normal acetabulum (fig. 1, *n.a.*) has undergone retrogressive modifications as the result of loss of function. Not only are its boundaries less well defined and prominent but its cavity has become reduced in depth by an invasion of osseous growth, so that it is somewhat shallower than the normal acetabulum of the *left* half of the girdle.

THE RELATIONSHIP BETWEEN THE INTERNAL STRUCTURE OF THE UPPER PART OF THE FEMUR AND FRACTURES THROUGH THE BASE OF THE NECK OF THE FEMUR.

By RALPH THOMPSON, Ch.M. (Vict.), F.R.C.S., *Demonstrator of Anatomy, Guy's Hospital.*

THE object of this paper is to show the important part which the internal structure of the femur takes, in connection with fractures of the neck of this bone, especially in that variety of fracture known as extracapsular.

In this variety of fracture the direction of the line of fracture which separates the head and neck from the rest of the bone, and the relation of this line to the capsule of the hip joint, need not be considered here.

When the head and neck are separated from the rest of the bone they are separated as a single fragment, which is driven forcibly into the great trochanter and upper part of the shaft of the femur, producing splitting of these portions of bone, as will be shown immediately.

An impacted fracture is thus produced; but the force of the blow causing the fracture may be too great, or the resistance of the bone into which the impaction takes place may be so small, that the portions of bone which are split may be so widely separated that disimpaction takes place.

If the separated fragment of the head and neck be examined, it will be found to bear a remarkable resemblance to those chisels used by masons in cutting bricks and slates, and which are known as "bolster chisels.' These chisels have a broad head, a narrow handle, and a very broad blade with a point at one end; in the case of the portion of head and neck, this point is situated at the lower end of the chisel.

If the blade of the chisel be examined, it will be found to be wedge-shaped.

In sections through the long axis of the chisel made at its centre, bone fibres will be seen radiating from the narrow part into the broad part of the neck. If, however, a section be made parallel with the former, but lower down the neck, the apex of the wedge, that is, the cutting edge of the blade, is formed by the "calcar femorale," as shown in fig. 2.

According to Hamilton and Gant, and as shown in all the specimens illustrating this paper, there are,in addition to the primary fracture, which, as we have seen, separates a chisel portion of bone from the shaft and

trochanteric region of the femur, two other lines of fracture commonly present, which pass through the great trochanter and upper part of the shaft of the femur.

These fractures may be called secondary. They may be distinguished as vertical and horizontal, although this is not quite an accurate description of their direction.

The first, or vertical, line of fracture runs from the front part of the summit of the great trochanter downwards and backwards, through the



FIG. 1.—Portion of head and neck separated as "bolster chisel"
* indicates lower end and point formed by "calcar femorale."

outer surface of the great trochanter and shaft of the femur to the lower part of the spiral line below the small trochanter, and then turns upwards and forwards to join the primary fracture at the lower and outer part of the neck of the femur.

The second or horizontal line of fracture passes from the posterior intertrochanteric line, just below the digital fossa, outwards and forwards, either slightly downwards or slightly upwards, through the base of the great trochanter, to meet the vertical line of fracture.

The causes producing these lines of fracture, including the primary line as well as the secondary lines, may now be considered.

First, the primary fracture may be considered.

In this, the line of fracture behind occurs under shelter of the posterior intertrochanteric line, where the compact line is exceedingly thin, and where the compact lamina forming the inner surface of the posterior intertrochanteric line or ridge passes into the compact lamina, forming the posterior surface of the neck. These two laminæ run into each other at, practically, an angle of 90°.

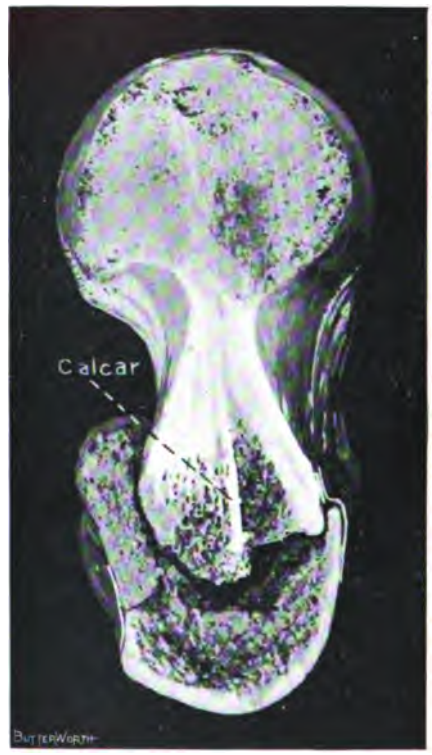


FIG. 2.—Transverse section of extracapsular fracture of neck of femur, showing "calcar femorale" forming cutting edge of "bolster chisel." (From a photograph.)

These two anatomical conditions are potent causes in determining the position of the posterior line of fracture: and, "*mutatis mutandis*," the upper limit of the fracture may be explained in the same way.

The anterior line of fracture occurs just where the thick compact lamina on the front of the great trochanter passes suddenly into the thinner compact lamina on the anterior surface of the neck.

The apex of the wedge and shape of the blade of the chisel of the head

and neck is formed, at any rate in the lower half of the neck, by the calcar femorale. Moreover, the lower limits of the fracture correspond to the lowest level of the "calcar femorale," as shown in the accompanying figure of an unimpacted extracapsular fracture (fig. 4).

This figure also shows the "calcar femorale" lying exactly opposite the secondary vertical line of fracture; but this relation is seen more

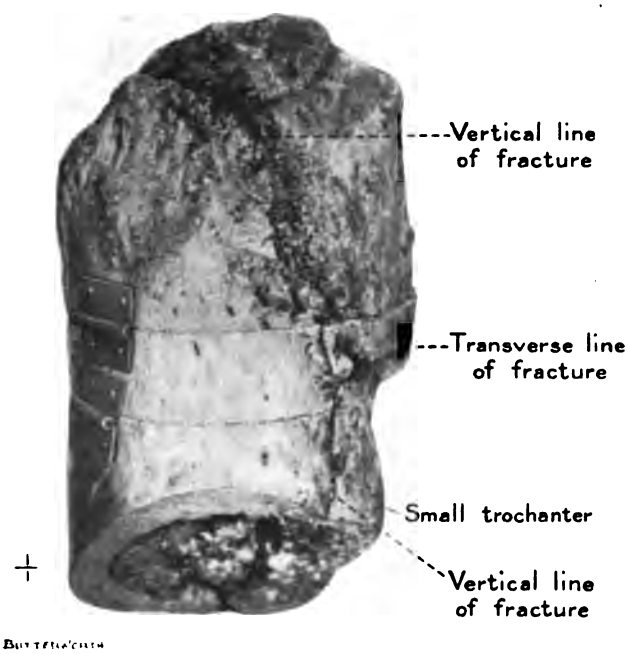


FIG. 3.—View of outer surface of upper end of femur, showing vertical and transverse secondary lines of fracture. (From a photograph.)

clearly in the accompanying diagram of a section representing an actual specimen.

This figure, as well as fig. 6, shows the "calcar" producing the secondary vertical fracture.

The vertical line of fracture may then be considered to be due to the calcar being driven against the great trochanter and upper part of the shaft of the femur.

The horizontal secondary fracture may be perhaps due to the rotation of the shaft of the femur backwards, which is practically always a prominent clinical sign of fracture of the neck of the femur. This rotation of

the shaft causes the posterior intertrochanteric ridge to impinge forcibly against the posterior surface of the neck, exactly where the calcar rises from the posterior compact lamina of the neck, as shown in the accompanying figure (fig. 6), and so the horizontal line of fracture is produced.

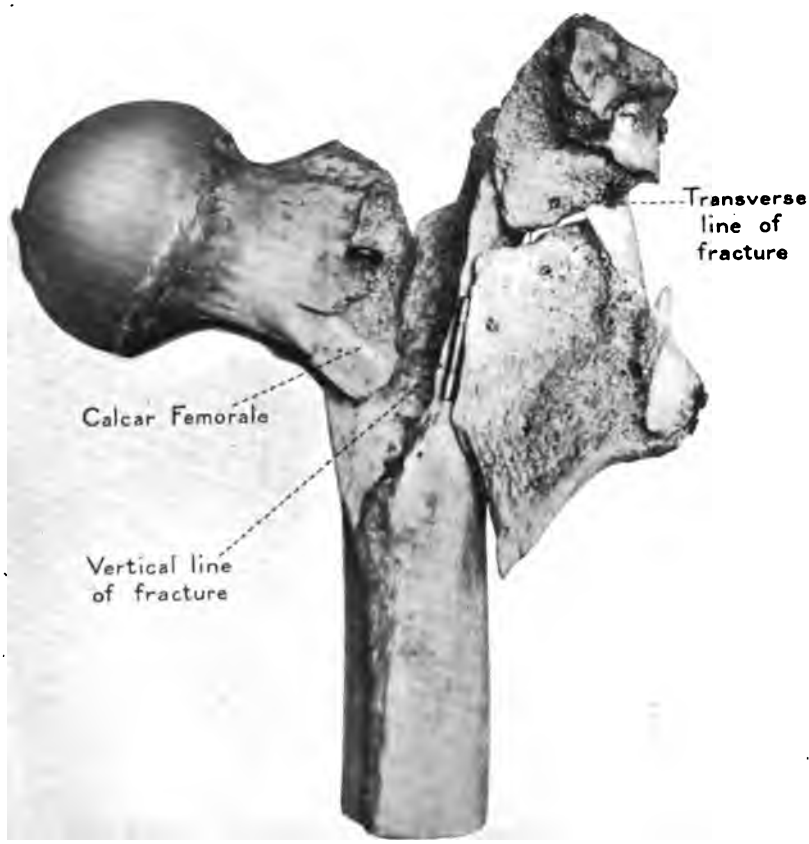


FIG. 4.—Unimpacted extracapsular fracture in male aged 87, showing calcar femorale lying opposite vertical line of fracture. (From a photograph.)

From the illustrations of actual specimens included in this paper, it may be concluded that the "calcar femorale" plays an important part in the production of the shape of the blade of the chisel portion of the head and neck separated from the rest of the bone, in that it not only forms and supports the cutting edge of the blade, but also its pointed lower limit.

When this chisel is driven into the great trochanter and upper part of

the shaft of the femur, its blade, formed and supported by the calcar, is certainly responsible for the vertical splitting of the shaft. The strengthening of the posterior compact lamina of the neck by the calcar may also be held responsible for the horizontal fracture.

A few remarks may now be made with regard to the anatomy of the "calcar femorale."

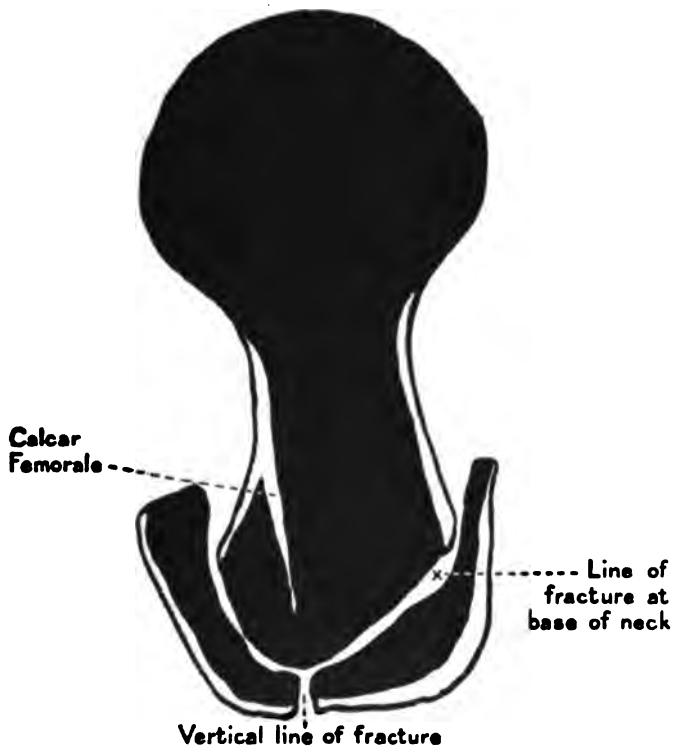


FIG. 5.—Outline drawing from specimen of "calcar femorale," producing vertical secondary line of fracture in transverse section.

The "calcar" may be studied in transverse sections of the upper end of the femur; or by sections parallel with the long axis of the neck; or, best of all methods, by adopting the plan recommended by Bigelow. In this method the outer surface of the lower part of the great trochanter and upper part of the shaft of the femur is removed by a trephine saw, and the cancellous bone beneath picked away with a sharp piece of steel.

The accompanying figure (fig. 7) represents the calcar after this plan has been adopted.

In such a specimen the "calcar" is seen as a nearly vertical ledge of compact bone, having an anterior surface, a posterior surface, an outer edge, and an internal attached base.

It passes downwards and slightly forwards, commencing above the

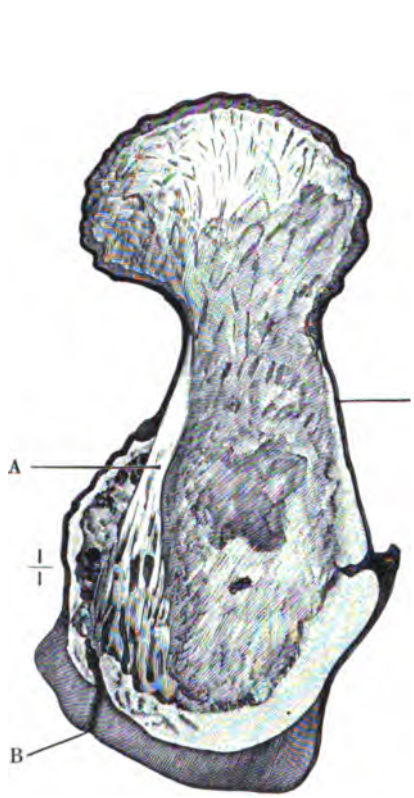


FIG. 6.—Showing same condition as preceding figure, and also posterior intertrochanteric ridge impinging against neck at point of origin of calcar femorale. A, "calcar femorale"; B, vertical line of fracture.

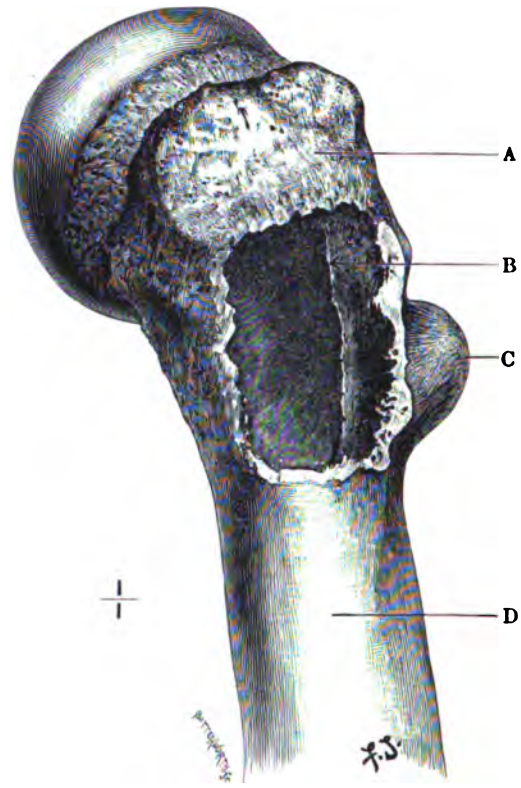


FIG. 7.—Showing "calcar femorale" in a normal femur. The bone has been prepared as indicated in text. A, great trochanter; B, calcar femorale; C, small trochanter; D, shaft of femur.

compact tissue of the posterior sloping surface of the neck, just beneath the groove for the obturator externus tendon on its way to the digital fossa, and terminating below by gradually fading away into the compact tissue of the shaft of the femur underneath, and external to, the upper part of the spiral line.

Roughly, it may be said to extend from the base of the great trochanter to the lowest part of the base of the lesser trochanter. The calcar is half

an inch deep or more in its deepest part, which is just above its centre; and its edge lies at the junction of the posterior and middle thirds of a line drawn between the anterior and posterior surfaces of the neck near its base.

The outer edge varies in position according to the depth of the calcar. It may be continuous with fine laminæ of bone, running nearly parallel with each other towards the compact layer on the outer surface of the upper part of the femur.

The "calcar" is said to disappear in old age, but the writer has collected specimens showing a well-marked "calcar" in males aged 67, 70, 71, 80, and 87, and in two females aged 65 and one aged 83.

In the case of the male aged 87 the "calcar" is well seen in the right femur, of which there was an unimpacted extracapsular fracture, and of which a photograph is shown in fig. 4; and there is also a good "calcar" in the left femur removed from the same case.

The "calcar" was not present in any femurs of fœtuses or very young infants which the writer examined, but there was a "calcar" present in three male subjects aged 3 years each, and in one female aged 6.

The "calcar" was not found in two subjects aged 21 and 27 respectively, the former a female, the latter a male.

The deposition of fat in the region of the neck of the femur may also be profitably considered here.

As age advances, fat is deposited in two places in considerable quantity, forming large globular masses at least half an inch in diameter. One of these masses of fat lies in the narrow part of the neck of the femur, near the head. The other mass lies in front of the anterior surface of the "calcar." The former deposit predisposes to intracapsular fracture of the neck of the femur; the latter to the splitting of the upper end of the femur described above, for in this case fat offers less resistance to the impaction of the fragment of head and neck separated.

A reference to sections passing through the neck of the femur in young adults shows that the cancellous tissue is much denser than in old people, and therefore we may expect that if a fracture through the base of the neck occurs in young people, the "calcar femorale" will not form such a dangerous weapon as in older people in whom fat is deposited.

There are now two difficulties to be considered in connection with the production of the secondary vertical fracture by the "calcar."

The first is that the splitting is much longer than the calcar: this may be explained by referring to the fact that the splitting which a chisel may produce is frequently much longer than the blade of the chisel itself.

The other difficulty is that, whilst the calcar runs downwards and forwards, the vertical fracture runs downwards and backwards.

In many cases, however, of fracture through the neck of the femur, flexion of the lower fragment is a marked clinical and anatomical feature. Flexion of the lower fragment brings the calcar exactly opposite to a parallel with the vertical line of fracture which is produced.

It is generally agreed that the "calcar" lies in the lines of pressure transmitted from the head to the shaft of the femur; and whilst it is denied by authorities that impacted extracapsular fracture follows upon falls on the feet, yet it is possible that such a condition might occur. In such a case the lower fragment being forced upwards by the fall, and dragged inwards by the tonic action of muscles and the upper fragment tending to rotate on an antero-posterior axis, the outer edge of the head and neck, that is, the blade of the chisel, is carried upwards, and cuts the trochanter and upper part of the shaft of the femur.

The conclusions arrived at in this paper may thus be briefly summarised:—

1. The "calcar" does not invariably disappear in old age.
2. The "calcar" is not invariably present even in young people.
3. The "calcar" in extracapsular fracture of the neck of the femur is responsible for the edge and lower end of a chisel, whose other parts are represented by the head and neck of the femur.
4. The "calcar" certainly produces the vertical secondary fracture of the great trochanter and upper part of the shaft of the femur, and may be held partially responsible for the horizontal secondary fracture near the base of the great trochanter.

The writer hopes to consider the function of the "calcar," as well as its development, in a future paper.

The photographs illustrating this paper have been taken by Mr A. S. Beale, and to him, as well as to the surgeons at Guy's Hospital, who have allowed me the use of specimens, I desire to record my hearty thanks.

ON THE BRAINS OF ABORIGINAL NATIVES OF AUSTRALIA IN THE ANATOMY SCHOOL, CAMBRIDGE UNIVERSITY.

By W. L. H. DUCKWORTH, M.D., Sc.D., M.A.

PART I.

FOUR brains of aboriginal natives of Australia are preserved in the Anatomical Museum at Cambridge. Drs Watson and Stirling obtained and presented these specimens, which (with one exception) were removed from heads of natives preserved in alcohol.

Some of the features of these brains have been described by Professor Macalister[1] and Dr Rolleston,[2] and the present writer has published notes[3] on the conformation of the rhinencephalon in this series. Hitherto, however, no comprehensive study has been published, and the present time seems opportune for such a publication, since recent work, especially that of Professor Elliot Smith, has added greatly to our knowledge of the criteria to be selected for comparative purposes.

One of the chief points of interest concerning the brains of Australian aborigines is their consideration in the light of evidence derived from the other anatomical systems of these natives. That evidence points to their lowly status, because of the frequent occurrence of characters very rare in the white races of mankind, but at the same time normal in the ape tribes. In fact, simian characters are frequent,[4] though the Australian aboriginal has by no means a monopoly of these. But the brains of these natives have seldom been studied, owing to the difficulty of procuring material. The question at once arises then, Does the conformation of the brain support the general conclusions (as to lowliness of status) suggested by the skeletal and other systems?

The answer to this question will depend upon a detailed examination of the specimens, and a preliminary investigation has been attempted, with the results to be set forth in the sequel.

In terminating these introductory remarks, two further considerations may be touched upon.

[1] Neurological Society, Cambridge Meeting, May 1900. No report was published.

[2] *Journal of the Anthropological Institute*, vol. xvii.

[3] *Morphology and Anthropology*, Pitt Press, Cambridge, 1904, pp. 423 *et seq.*

[4] The total number of memoirs barely exceeds half a dozen. In addition to those already mentioned (footnotes 1, 2, 3), only the following references are known to the writer:—Miklucho-Maclay, *Proc. Linn. Soc. of N.S. Wales*, vol. ix.; Karplus, *Obersteiner's Arbeiten*, Vienna, 1902, Heft ix.; Flashman, *Reports from the Pathological Laboratory of the Lunacy Department, N.S. Wales*, vol. i., 1903.

In the first place, and speaking generally, when anomalous conditions of an anatomical nature are discovered, the observer has to guard himself against a tendency to see evidence of simian or other lowly relations and ancestry in all alike. In the present case this tendency has not been overlooked, and in particular, the existence of a type of anomaly which is referable to persistence of an immature (even a fœtal) condition, has been particularly borne in mind. Indeed it seems that many distinctive features in the anatomy of the so-called "lower" races may be better explained thus than in any other way. And though in some instances the retention of an infantile character may also be claimed as reminiscent of a simian ancestry, nevertheless this is not always the case.

In the second place, there is no likelihood of mistaking these Australian brains for anything but human specimens. They are at once distinguishable from the most highly-developed simian brain by the following characters: (*a*) the elongation of the whole cerebrum, which finds particular expression in (i) the backward prolongation of the occipital lobe, and (ii) the antero-posterior elongation with flattening (in the vertical sense) of the temporal lobes. (*b*) The development and exuberance of the opercular folds overlapping the insula (or central lobe); and in this connection, the submergence of the simian sulcus fronto-orbitalis, here represented by the so-called anterior limiting sulcus of Reil, should be noted.

With such introductory observations the study of the specimens may be commenced, and to facilitate comparisons between the various specimens the following plan or scheme of work was adopted:—

Section 1. Enumeration of the characters which have proved useful for purposes of comparison. To this section bibliographical notes are appended, so that reference may be made to the more recent literature.[1]

[1] *General Note on Literature.*—For convenience in detailed references, the following abbreviations will be employed:—

E.S.Cat. = *Catalogue of the Physiological Series, Museum of the Royal College of Surgeons of England*, second edition, 1902: "The Cerebrum of Higher Vertebrates," by Elliot Smith.

E.S.Gov. = *Records of the Egyptian Government School of Medicine*, vol. ii.: Elliot Smith, "Studies in the Morphology of the Human Brain: No. 1, The Occipital Region," Cairo, 1904.

Cu.vii. = *Royal Irish Academy, Cunningham Memoirs*, vii.

C. and T.S. = Cunningham and Telford Smith, "The Brain of the Microcephalic Idiot," *Scientific Transactions of the Royal Dublin Society*, vol. v., series ii.

E.S.J.A.P. = Elliot Smith, in the *Journal of Anatomy and Physiology.*

J.A.P. = *Journal of Anatomy and Physiology.*

Retzius M. = *Das Menschenhirn*, Stockholm, 1896, G. Retzius.

Linn.Trans. = *Transactions of the Linnean Society.*

E.S.Anat.Anz. = Elliot Smith, in the *Anatomischer Anzeiger.*

J.A.I. = *Journal of the Anthropological Institute.*

Section 2. The characters enumerated in the foregoing section having been observed in the four Australian brains, the results of the observations are next commented upon.

Section 3. Some of the results are exhibited here in the form of tabular statements.

Section 4. In this section an attempt is made to summarise the results, and the evidence drawn from the observations.

Section 5. Detailed descriptions of the respective specimens are appended as a separate section.

Section 1.

Complete List of the Characters dealt with in this Memoir.

Out of the very large number of cerebral characters to which the attention of anatomists has been turned, the following selection has been made, as comprising those most appropriate to the object in view:—

1. The general form and proportions of the cerebra:
   - (*a*) Actual dimensions.[1]
   - (*b*) Proportions.[2]
   - (*c*) Rostration at the frontal end.[3]
   - (*d*) "Square-cut" contour at the occipital end.[4]
   - (*e*) Flattened areas correlated with the "ill-filled" crania found among aborigines of Australia.[5]
   - (*f*) The general arrangement and direction of the sulci.[6]
   - (*g*) The comparative amounts of the hemisphere in front of and behind the corpus callosum.[7]
   - (*h*) The direction of the axis of the temporal lobe.[8]
2. The Rhinencephalon:
   - (*a*) The olfactory nerve.[9]
   - (*b*) The tuber olfactorium.[10]
   - (*c*) The diagonal band of Broca.[11]

[1] *Quain's Anatomy*, vol. iii., part i., p. 176 (1893).
[2] *Quain's Anatomy*, vol. iii., part i., p. 176 (1893).
[3] E.S.Cat., p. 440, footnote; *ibid.*, p. 431.
[4] E.S.Gov., p. 150. [5] Cleland, *Phil. Trans. Roy. Soc.*, 1869.
[6] See reference 1; also Cu. vii., p. 190, with references to the work of Calori, Meyer, and Rüdinger.
[7] C. and T.S., p. 329, with reference to Aeby's work in the *Archiv für Anthropologie*, 1873, Band vi. [8] Cu. vii., p. 146. [9] E.S.J.A.P., xxxv., pp. 433 *et seq.*
[10] Retzius, *Menschenhirn*, text, p. 72; Barker, "The Nervous System," p. 754.
[11] E.S.Cat., p. 440; also E.S.J.A.P., xxxvii., p. 325; also Waldeyer, *Das Gibbon-Hirn*, p. 59.

(*d*) The rhinal fissure and the sulcus inferior rhinencephali of Retzius.[1]

(*e*) The uncus.[2]

(*f*) The gyrus A. Retzii.[3]

3. The Neopallium: the following divisions of this part of the cerebrum will be considered successively.

The Sylvian and central regions:

(*a*) The Sylvian vallecula.[4]

(*b*) The opercula.[5]

(*c*) The anterior limbs of the Sylvian fissure.[6]

(*d*) The fronto-orbital sulcus.[7]

(*e*) The limbus post-orbitalis.[8]

(*f*) The inferior precentral sulcus in relation to the Sylvian fissure.[9]

(*g*) The sulcus subcentralis anterior in relation to the Sylvian fissure.[10]

(*h*) The posterior limb of the Sylvian fissure:[11] (i) its length and connections, (ii) its angle of inclination, (iii) its position on the hemisphere.

(*i*) The central sulcus (Rolando):[12] (i) the Rolandic angle, (ii) the fronto-Rolandic indices, (iii) the depth of this sulcus.

(*j*) The sulci of the insula Reilii.[13]

4. The Neopallium (*continued*)—The frontal region.

(*a*) The sulci of the frontal lobe taken in succession.[14]

(*b*) The sulci of the orbital surface.[15]

[1] Retzius M., p. 74. (Symington, *J.A.P.*, April 1906, advances a theory to the effect that Retzius's sulcus inferior rhinencephali is really caused by the pressure of the free margin of the tentorium cerebelli.)

[2] Statement based on the examination of several Hylobates' brains in the Cambridge Anatomical Museum.

[3] E.S.J.A.P., xxxii., Oct. 1897; also E.S.Linn.Trans., vol. vii., part iii., June 1897; also Retzius M., p. 164.

[4] E.S.Cat., p. 411; also *ibidem passim*, esp. pp. 390 and 400.

[5] Cu vii., p. 83; Retzius M., pp. 113 *et seq.*

[6] Cu. vii., pp. 86, 92.

[7] E.S.Cat., p. 462 *et passim* (esp. pp. 398, 430, 472); E.S.J.A.P., xxxviii., p. 158.

[8] E.S.Anat.Anz., Band. xxiv., 1904.

[9] E.S Cat., pp. 432, 437, 438; Retzius M., pp. 101, 102, 158; Cu. vii., pp. 248–250; Waldeyer, *Anat. Hefte*, 1897.

[10] Retzius M., pp. 101, 102.

[11] Cu. vii., p. 133.

[12] Cu. vii., pp. 161, 164, 165; Retzius M., p. 98; Miklucho-Maclay, *Proc. Linn. Soc. N.S.W.*, vol. ix.; Bolk, *Petrus Camper*, Di. iii., Afl. 2.

[13] Cu. vii., p. 97; Retzius M., pp. 148–150.

[14] Cu. vii., pp. 244–305; Retzius M., p. 103; E.S.Cat., pp. 402, 432, 433, 436.

[15] E.S.Cat., p. 398; Retzius M., p. 109.

5. The Neopallium (*continued*)—The parietal region.
   (*a*) Fulness or attenuation of the parietal lobe.[1]
   (*b*) Conformation and depth of the sulcus intraparietalis.[2]
   (*c*) Relative size of the arcus parieto-occipitalis.[3]
   (*d*) Relative length of the horizontal component of the sulcus intraparietalis.[4]
6. The Neopallium (*continued*)—The occipital region.
   (*a*) The retrocalcarine sulcus and limiting sulci.[5]
   (*b*) The occipital sulci, including the sulcus lunatus or Affenspalte.[6]
   (*c*) The parieto-occipital fossa and adjacent sulci (viz. the s. paracalcarinus, s. limitans precunei, and incisura parieto-occipitalis).[7]
   (*d*) The gyrus cunei and the annectant gyri in the retrocalcarine sulcus.[8]
7. The Neopallium (*continued*)—The temporal region.
   (*a*) The temporal sulci.[9]
   (*b*) The first temporal gyrus.[10]
   (*c*) The collateral sulcus.[11]
   (*d*) The projection of the pole of the temporal lobe.[12]
8. The Neopallium (*continued*)—The mesial aspect so far as it is not included under the preceding headings.
   (*a*) The sulcus intercalaris, especially in its relation to other sulci.[13]
   (*b*) The sulcus compensatorius.[14]
   (*c*) The incisura cinguli.[15]
   (*d*) The genual and rostral sulci.[16]
9. The Cerebellum.[17]

[1] Bastian, *The Brain as an Organ of Mind*, pp. 384, 398.
[2] Cu. vii., pp. 194-220; Retzius M., p. 119; C. and T.S., p. 310.
[3] Cu. vii., p. 238; Rolleston, J.A.I., vol. xvii. [4] Cu. vii., p. 241.
[5] E.S., *Proc. Roy. Soc.*, 1904, vol. lxxiii., p. 59; E.S.Gov., pp. 128, 129 (full references); Cu. vii., pp. 32 *et seq.*; Retzius M., p. 136.
[6] E.S.Cat., pp. 438, 473; E.S.Anat.Anz., xxiv., pp. 74-83; E.S.Gov., pp. 149-169.
[7] E.S.Gov., pp. 145-149; E.S.J.A.P., xxxviii., p. 164.
[8] Cu. vii., pp. 36-45; Quain, vol. iii., part i., p. 144 (1893).
[9] E.S.Cat., pp. 368, 416, 419, 433, 438; Retzius M., pp. 140, 142, 144, 145.
[10] Retzius M., pp. 145, 146.
[11] C. and T.S., pp. 325, 326; E.S.Cat., pp. 386, 398, 406; Retzius M., p. 139; Waldeyer. *Das Gibbon-hirn*, p. 54; Cu. vii., p. 71. [12] C. and T.S., p. 327.
[13] E.S.Cat., pp. 387, 447; Retzius M., pp. 77, 100; C. and T.S., p. 312.
[14] E.S.Cat., pp. 386, 387, 399; Retzius M., p. 121.
[15] E.S.Gov., fig. 17; Retzius M., p. 120.
[16] E.S.Cat., pp. 176 *et passim*; Retzius M., p. 80.
[17] E.S.Cat., pp. 430, 448, 458.

Section 2.

Introductory Note.—In the following paragraphs the mode of occurrence of the central characters enumerated in the preceding section (1) is noted and criticised. In several instances the records lend themselves to a numerical mode of expression; reference will be necessary, therefore, in those cases to the tabulated statements which will be found in Section 3.

1. The general form and proportions.
   - (*a*) In point of size, the cerebra are distinctly below the average of European brains, but considerably surpass those of the largest Simiidæ. At the same time, the specimens are curiously variable: thus No. 1 (figs. 1 and 2) is the smallest, and as its dimensions (*cf.* Table I., part 1) show, it is distinctly justifiable to describe it as microcephalic; No. 2, on the other hand, the largest of the series, is not far below the average of European brains.
   - (*b*) The proportions of the cerebra are dolichocephalic, as is indeed to be expected, in view of the great preponderance of crania of markedly dolichocephalic proportions among the aborigines of Australia. The brains of the Simiidæ vary in this respect, but tend to brachycephalic proportions.
   - (*c*) The character known as "rostration" (due to the adaptation of the cerebrum to the basal surface of the anterior cerebral fossa) is here obscured. This is due entirely to the inadequate means employed to secure preservation, since the study of endocranial casts shows that distinct rostration obtains. In the present series, the appearance would be exaggerated were the material properly preserved, by reason of the comparative attenuation of the frontal lobes, which is marked in Nos. 1, 3, and 4, though less so in No. 2. If exaggerated, the conformation would be claimed as a simian feature, though no great stress can be laid upon this particular point alone.
   - (*d*) In addition to its attenuated appearance (as compared with the corresponding part of the European brain), the occipital lobe exhibits in lowly human brains a "square-cut" contour which it shares in common with brains of gorilla (and some instances among those of other Simiidæ). This character is distinct in one hemisphere of the present series, viz. the left hemisphere of No. 2; but not remarkable in any other, although imperfect preservation affects this feature also.

(*e*) The aboriginal Australian cranium presents an appearance described by the term "ill-filled." Reference is here made to the flatness of the exocranial surface on either side of the mesial plane, in the frontal and parietal regions respectively. As compared with European crania, that of the aboriginal Australian appears to be incompletely expanded, and this is ascribed to comparatively defective growth of the cerebrum.

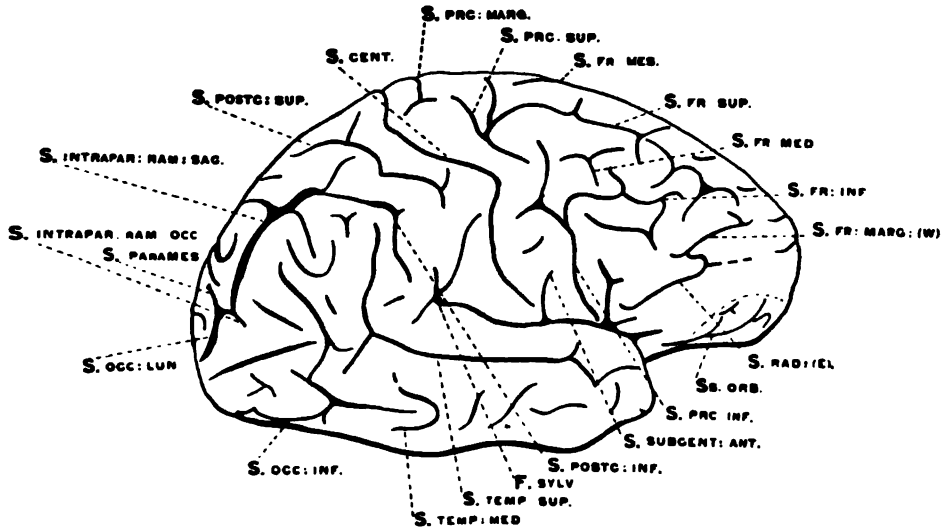


FIG. 1.—Australian brain No. 1. Right hemisphere. Lateral aspect.

The following abbreviations are used in this and the succeeding illustrations of the lateral aspects of the brain:

S. subcent. ant.	Sulcus subcentralis anterior.
S. prc. inf.	Sulcus precentralis inferior.
Ss. orb.	Sulci orbitales.
S. rad. (*E.*)	Sulcus radiatus of Eberstaller.
S. fr. marg. (*E.*)	Sulcus fronto-marginalis of Eberstaller.
S. fr. marg. (*W.*)	Sulcus fronto-marginalis of Wernicke.
S. fr. inf.	Sulcus frontalis inferior.
S. fr. med.	Sulcus frontalis medius.
S. fr. sup.	Sulcus frontalis superior.
S. fr. mes.	Sulcus frontalis mesialis.
S. prc. sup.	Sulcus precentralis superior.
S. prc. marg.	Sulcus precentralis marginalis.
S. centr.	Sulcus centralis of Rolando.
S. poste. sup.	Sulcus postcentralis superior.
S. intrapar. ram. sag.	Ramus sagittalis of the sulcus intraparietalis.
S. intrapar. ram. occ.	Ramus occipitalis of the sulcus intraparietalis.
S. parames.	Sulcus paramesialis.
S. occ. lun.	Sulcus occipitalis lunatus.
S. occ. inf.	Sulcus occipitalis inferior.
S. temp. med.	Sulcus temporalis medius.
S. temp. sup.	Sulcus temporalis superior.
F. Sylv.	Fissura Sylvii.
S. poste. inf.	Sulcus postcentralis inferior.
S. occ. sup.	Sulcus occipitalis superior.
S. retrocalc.	Sulcus retrocalcarinus.

The character is not found in the crania of apes, for in these the exocranial surface is subject to influences (viz. those associated with the size and extent of the temporal muscles) from which all human crania, including the lowest, are comparatively free. Endocranial casts of Australian crania

reveal corresponding areas of flattening on the cerebral surface. The brains here considered do not, if we except No. 2, exhibit this feature, but again the lack of adequate preservation must probably be held responsible for its absence.

(*f*) As regards the general direction of the sulci, an evident tendency to a longitudinal disposition is seen in the Australian hemispheres. This character is neither distinctly

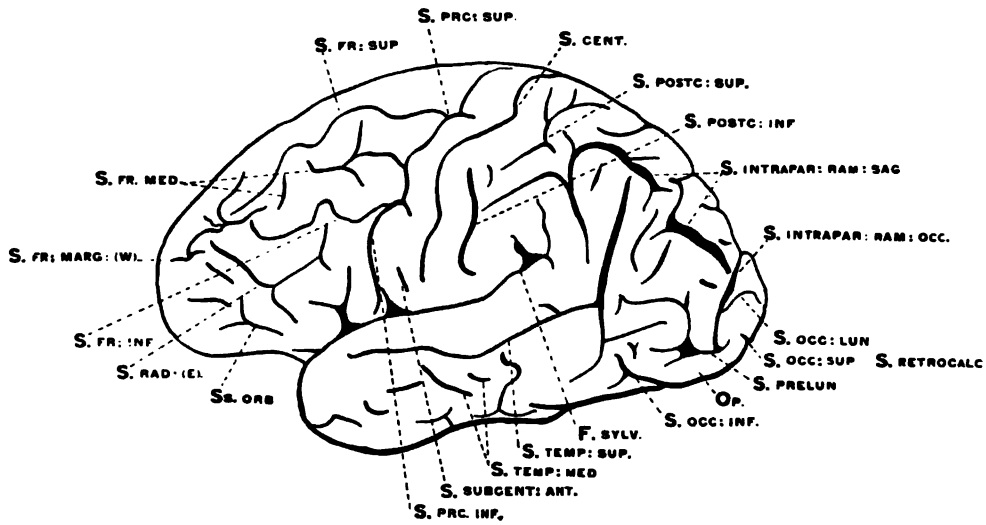


FIG. 2.—Australian brain No. 1. Left hemisphere. Lateral aspect.

fœtal nor simian. It is determined largely by the dolichocephalic proportions of the cerebrum as a whole. The foregoing remarks apply to the lateral convexity of the brain. No general remarks can be made with reference to the mesial aspect, which is not differentiated in this respect from either simian or from highly-developed human brains. Nor can a comparison be instituted (in regard to either the lateral or mesial aspects) between the Australian brains and fœtal brains of European origin.

(*g*) The proportionate amounts of the hemisphere situated anteriorly and posteriorly to the corpus callosum are exhibited in a table (*q.v.* Section 3, Table I., part 1). For comparison,

the data provided by Cunningham and Telford Smith,[1] and by Aeby,[2] are available, but I have confined myself to the former, as being more reliable. (Aeby's data are largely derived from illustrations, whereas those of Cunningham and Telford Smith are based on measurements made upon the actual brains while still *in situ* within the bisected crania.) If one may rely upon measurements derived from somewhat distorted specimens, such as these Australian brains, one concludes that no distinct approximation to either simian or (European) fœtal conditions obtains in the former. The greatest resemblance is found, however, between the Australian brains and European microcephalic cerebra. Probably a common cause is responsible in both cases, and it will be found in the mechanical arrangements attendant upon defective growth, which need not in either case be regarded as pathological in nature, although certain varieties of European microcephalous brains are undoubtedly the products of pathological interference with normal developmental processes.

(*h*) The direction of the long axis of the temporal lobe has been appealed to as affording a means of distinguishing simian from non-simian types of cerebrum. In this respect the Australian brains exhibit no simian resemblances, but on the contrary are distinctly human. Nor can it be said that they resemble the fœtal, rather than the adult form of European brain.

2. The Rhinencephalon.

(*a*) The olfactory bulbs and nerves present no special features. They are particularly well preserved in both hemispheres of Brain No. 3.

(*b*) In no hemisphere is the tuber olfactorium distinguishable on the surface.

(*c*) In three hemispheres (No. 3, R. and L.; No. 4, L.) the diagonal band of Broca is distinct. In the remaining five hemispheres the band cannot be distinguished.

(*d*) The fissura rhinalis.

(i) In four out of the eight hemispheres this fissure is in some way connected with the anterior end of the sulcus collateralis. The anterior part of the latter sulcus may be detached from the main furrow; and the fissura rhin-

[1] C. and T S., p. 329. [2] *Archiv für Anthropologie*, 1873, Band vi.

alis, in two out of the four cases mentioned, is represented by two furrows. To sum up, it appears therefore that some mode of connection between the fissura rhinalis and the sulcus collateralis is noticed in 50 per cent. of hemispheres.

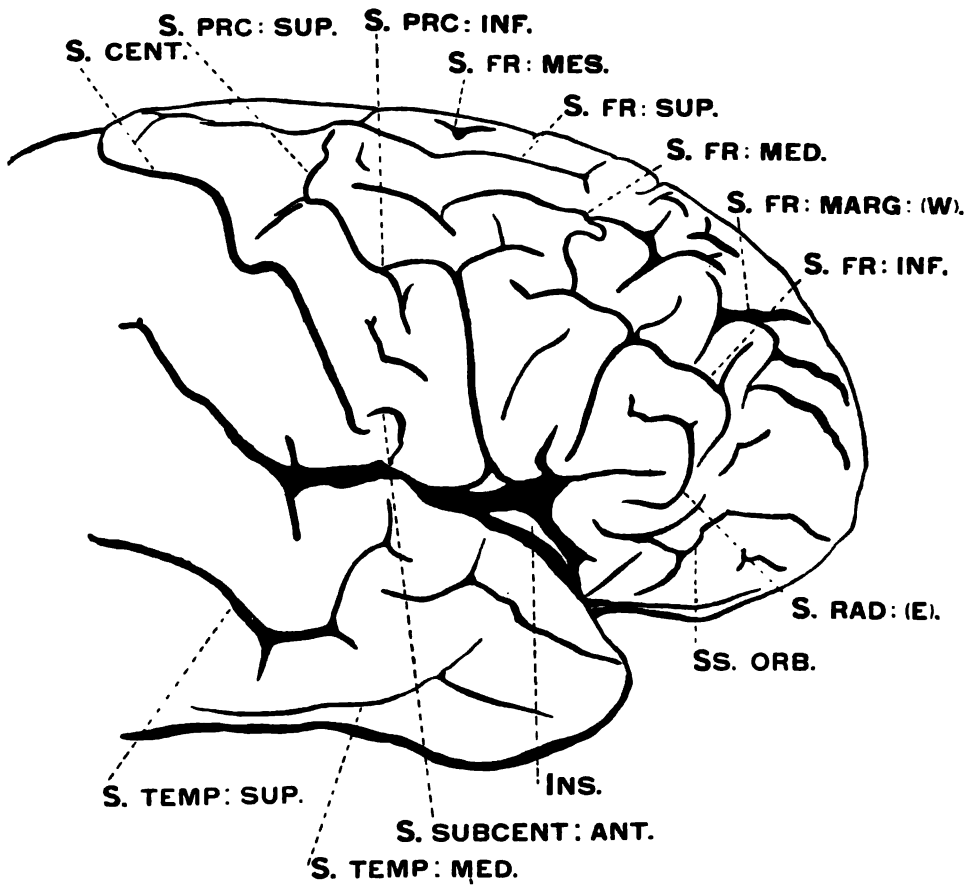


FIG. 3.—Australian brain No. 2. Right hemisphere. Lateral aspect.

(ii) In one hemisphere (12·5 per cent.) the fissura rhinalis is boldly curved as in the cerebra of the Simiidæ. This character has been described in the brains of Soudanese negroes by Elliot Smith, and I have the brain of a negro from West Africa in which the conformation is similar

to these. The brain of a young Zulu in the Hunterian Museum exhibits the same feature, which may be considered a distinctive mark of the lowlier type of human cerebrum.

(iii) Single hemispheres show that the variations to which the

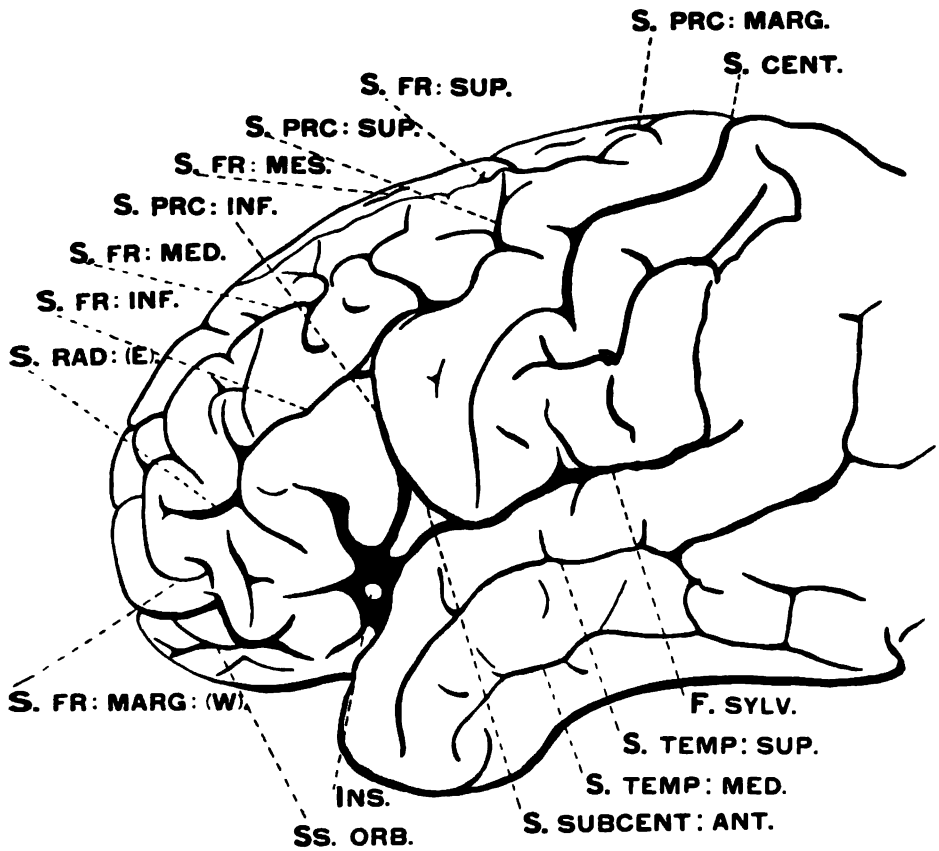


FIG. 4.—Australian brain No. 2. Left hemisphere. Lateral aspect.

rhinal fissure is subject are numerous, and include instances of the extremes of length, of brevity, and also of unusual position, for in one case the representative of the fissure has an almost vertical direction. In no instance can the sulcus inferior rhinencephali be identified. Retzius records its occurrence in 54 per cent. of Swedish brains. But doubt has recently been cast upon

the current view as to the morphology of this sulcus (*cf.* Symington, p. 72, *n.* 1).

(iv) The uncus is much flattened in the seven hemispheres in which it is visible. Such flattening is a simian, or more particularly a hylobatian, character, but so subject to post-mortem changes that little reliance can be placed upon records of such specimens as are here the subjects of comment.

(v) In four hemispheres the "Balkenwindung" or "Gyrus A. Retzii" is distinctly visible. It is most distinct in the well-preserved specimen No. 3. In Brain No. 2 (the largest) the gyrus is diminutive and not exposed. In No. 1 the state of preservation admits of no certain statement as to its conformation. Retzius records the presence of this gyrus in 55 per cent. of Swedish brains (*cf.* p. 72, *n.* 3).

The Neopallium will be treated of under the following headings:—

3. The Sylvian and central regions:

(*a*) The Sylvian vallecula appears somewhat widely open in five hemispheres, and this is due, no doubt, to the disturbance involved in the removal of membranes and blood-vessels. In one case in which the vallecula is wide, defective development of the orbital operculum seems distinctly responsible, though this cause cannot be called upon to account for a similar condition in another hemisphere. In three hemispheres the vallecula is fully as narrow as in European brains.

(*b*) In seven hemispheres (87·5 per cent.) some defect in the development of the opercula was noticed. In the remaining case no such defect exists. In the defective instances the orbital operculum is the part responsible for the exposure of the insula, and in one of these cases (Brain No. 3, right hemisphere) the frontal operculum is also smaller than in European brains.

In each case in which the opercular folds are incompletely formed, some exposure of the insula (central lobe) co-exists. But the amount of insula exposed in several of the cases of defective operculation is much greater than can be accounted for by this cause alone. It follows that in the process of removing the cerebral membranes the lips of the several parts of the Sylvian fissure have been torn apart.

(*c*) The following observations were made on the anterior limbs of the fissure of Sylvius :—

The anterior ascending limb is present in all the hemispheres. In one hemisphere (No. 1, R.) this limb is seen to be bifurcate.

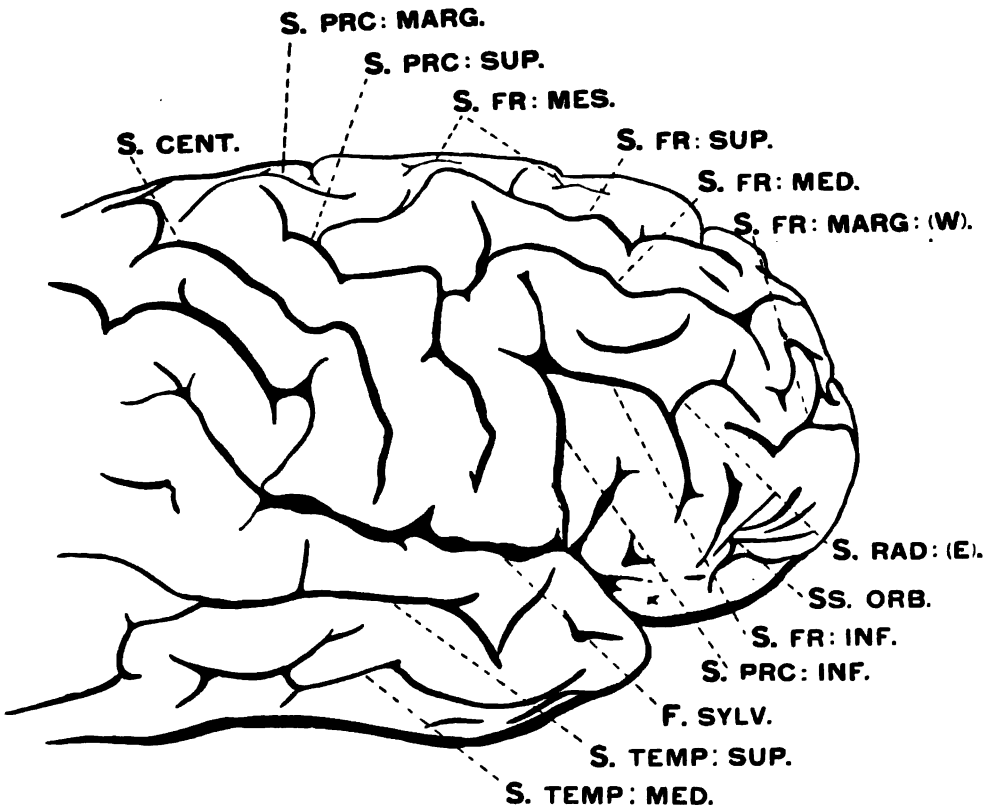


FIG. 5.—Australian brain No. 3. Right hemisphere. Lateral aspect.

The anterior horizontal limb cannot be identified in one of the hemispheres (viz. No. 3, R.), though it may be represented by a small depression or dimple near the situation of the normal sulcus. It thus appears that the anterior horizontal limb may be absent in 12·5 per cent of hemispheres. With this record we may compare that (30 per cent.) provided for British brains by Cunningham, and Retzius's figure of 14 per cent. (for Swedish brains) seems compar-

able, but indicative of the wide range of variation in these characters.

Where two anterior limbs are present, these are conjoined in three hemispheres, all being of the left side This proportion (37·5 per cent.) agrees with the figure provided by European brains (32·5 per cent.).

Independence of the two anterior limbs occurs in four hemispheres (50 per cent.), three being of the right side and one of the left. The corresponding proportion in European brains is 37·5 per cent.

No orbital limbs of the Sylvian fissure are recognisable in the left hemisphere of Brain No. 4. In two hemispheres (No. 4, R.; and No. 2, L.) two orbital limbs occur; in the remaining five hemispheres a single orbital limb is found. These records provide percentage proportions as follows:—

No orbital limbs . . .	12·5 per cent.
Internal orbital limb only . .	12·5 „
External „ „ „ . .	50 „
Both orbital limbs . . .	25 „
	100

(*d*) The sulcus fronto-orbitalis is now identified (*cf.* p. 72, *n.* 7) with the anterior limiting sulcus of Reil. In one hemisphere (No. 4, L.) this sulcus is clearly visible and exposed, such exposure constituting a very simian trait and resemblance.

In four hemispheres the sulcus is easily detected, but evidently was not superficial in the recent brain. In the remaining three hemispheres the sulcus is as completely submerged as in normal European brains.

On the whole, no stress can be laid upon the mode of occurrence of this sulcus, owing to the faulty preservation of the specimens. No. 4, in which the sulcus is most exposed, has been cut up into several blocks, and this process may have altered the relations of the sulcus to surrounding structures.

In no case can the writer recognise a post-orbital limbus.

(*e*) The inferior precentral sulcus (s. arcuatus) joins the Sylvian fissure directly in five hemispheres (71 per cent.), the condition in one hemisphere being uncertain. In each case the bond of union is apparently the sulcus diagonalis.

Cunningham found this confluence in 22 per cent. of British hemispheres, but quotes Giacomini as having found it in 68 per cent. of European brains. Retzius's figure for Swedish brains is 38 per cent.

In none of these instances is the opercular margin cut right

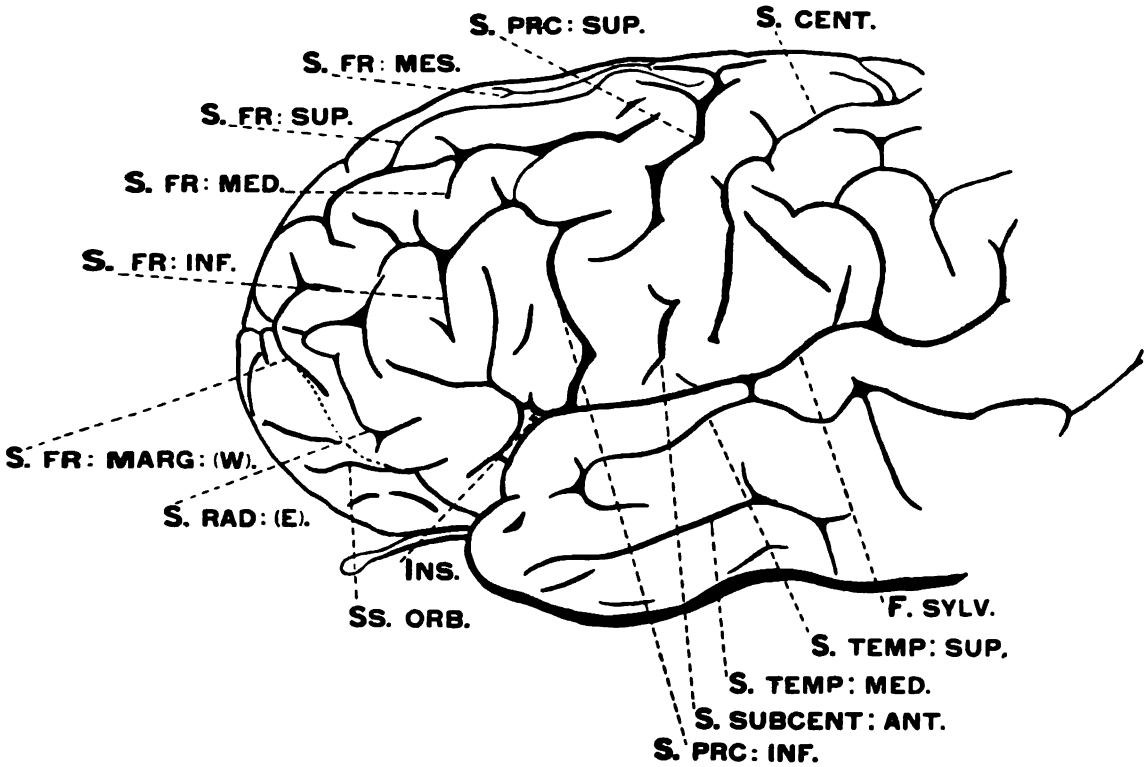


FIG. 6.—Australian brain No. 3. Left hemisphere. Lateral aspect.

through by the inferior precentral sulcus on its way to the Sylvian fissure.

In one hemisphere (Brain No. 3, R.) a slightly different condition obtains, for here part of the sulcus arcuatus joins the sulcus frontalis inferior, and this makes a superficial connection with the Sylvian fissure, and again the connection seems to be provided by the sulcus diagonalis.

In another instance (Brain No. 2, L.), the sulcus precentralis inferior is almost joined by the sulcus subcentralis anterior,

which being confluent with the Sylvian fissure, nearly provides another mode of connection between these two furrows. Cunningham (Cu. vii., p. 250) mentions a similar instance in a European brain. Retzius (*op. cit.*, p. 158) records the confluence of the inferior precentral sulcus through the anterior subcentral sulcus with the Sylvian fissure, in 9 per

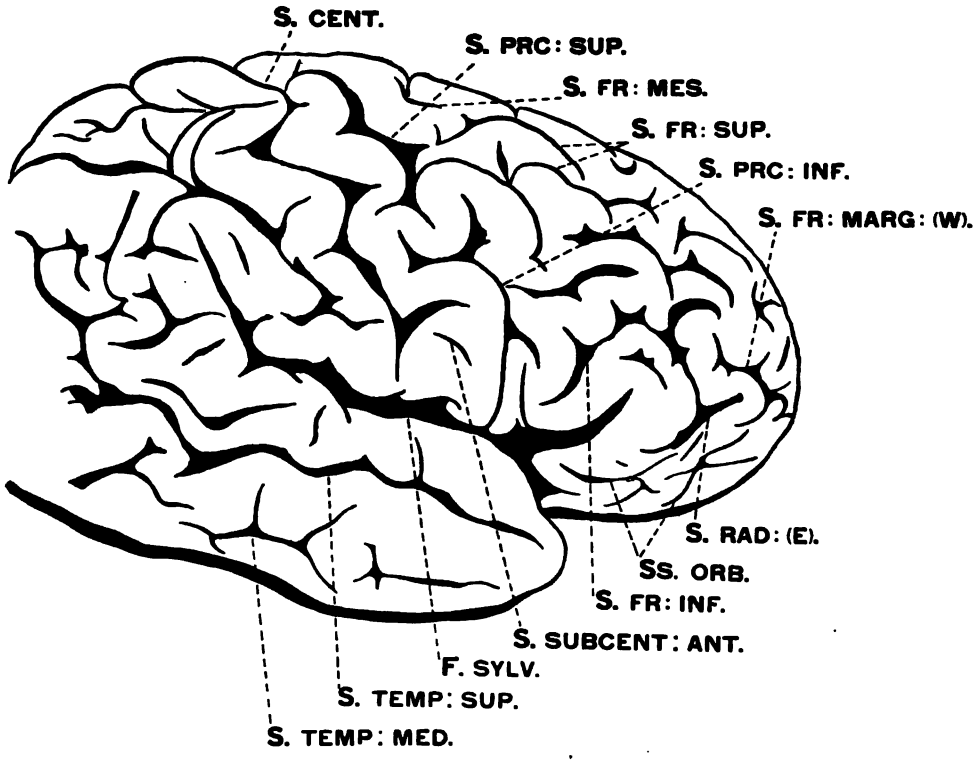


FIG. 7.—Australian brain No. 4. Right hemisphere. Lateral aspect.

cent. of Swedish brains. The union of the inferior precentral sulcus with the Sylvian fissure in one or other of the modes just described seems to be distinctly more frequent in female European brains, but this sexual difference is not apparent in the Australian series.

(*f*) The sulcus subcentralis anterior is present in seven hemispheres (87·5 per cent.). In four hemispheres it is detached from all other sulci; in two hemispheres (Brain No. 2) it

joins the Sylvian fissure (the junction being very superficial in one of these); while, as just mentioned, in one case it nearly joins the inferior precentral sulcus in addition to joining the Sylvian fissure. In one hemisphere (Brain No. 1, L.) the exact conformation is obscure.

This sulcus (the anterior subcentral) is present in the Simiidæ (though not with absolute constancy), often forming a means of confluence between the central sulcus and the Sylvian fissure. It also probably subserves this purpose in the Australian brains described by Miklucho-Maclay,[1] where the confluence of these two furrows is particularly mentioned and claimed as characteristic of Australian aboriginal brains.

(*g*) The observations and measurements connected with the posterior limb of the Sylvian fissure may be next considered. The relative length of this part of the Sylvian fissure (*cf.* Section 3, Table I., parts 1, 2, 3, and analysis) exceeds the value provided by European adult brains. The general outcome of the comparisons recorded in this table (I.) is that in this respect the Australian brains differ from those of adult Europeans while approaching (i) those of the Simiidæ, and (ii) almost as distinctly those of European fœtuses.

The values for the Sylvian angle (angle of the Sylvian fissure) do not distinguish these Australian brains from those of Europeans, but in one instance (Brain No. 3, R.) similarity is found with the European fœtus or infant rather than with the adult European.

The analysis of the data relating to the position of the posterior limb of the Sylvian fissure is complex. The chief indication is that of divergence from the fœtal European type: the closest resemblance is, on the whole, with the brains of adult Europeans, but in two cases the Simiidæ, and in one case the Cercopithecidæ, provide the closest likeness.

(*h*) In no case does the central sulcus communicate with the Sylvian fissure, either directly or through the inferior transverse (anterior subcentral) or the diagonal sulci. (The general statement made by Miklucho-Maclay, as to the prevalence of such a continuity, thus fails to receive confirmation from this series of brains.) In one hemisphere (14·3 per cent.) a very indirect connection occurs through

[1] *Proc. Linn. Soc. N.S. Wales*, vol. ix. I notice that this explanation is given also by Bolk in his account of a Papuan brain in *Petrus Camper*, Di. iii. Afl. ii.

the inferior postcentral sulcus, and hence *via* the posterior subcentral sulcus.

The upper end of the sulcus is likewise free and in every instance reaches, though it hardly passes beyond, the convex upper cerebral margin. Retzius (*op. cit.*) records confluence with the Sylvian fissure through the posterior subcentral

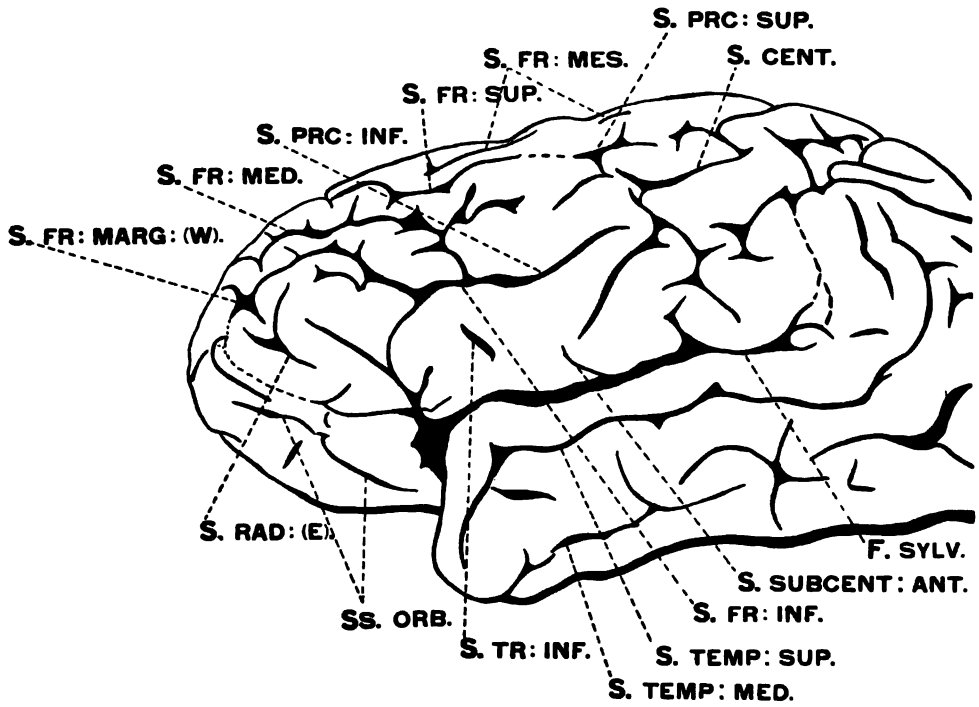


FIG. 8.—Australian brain No. 4. Left hemisphere. Lateral aspect.

sulcus in 7 per cent. of Swedish brains, and failure to reach the upper cerebral margin in 20 per cent. (also of Swedish brains).

The values of the Rolandic angle are most perplexing: though measured with great care upon tracings, I can find no approximation to the figures for adult European brains as quoted by Cunningham (*C. Memoir*, vii. p. 188). Moreover, three European brains, used as controls, gave equally divergent results from Cunningham's data. The only

conclusion arrived at is that the Australian brains provide a smaller angle than many European brains, and so far are simian, though their dolichocephalic proportions may be responsible for this result. The figures obtained are within the range of variation for both adult European brains and simian brains alike. These data are recorded in tabular form in Section 3, Table I., part 1 (*q.v*).

The fronto-rolandic indices give more definite information. Taking first the mesial index, it will be seen from Table I. (parts 2, 3, and analysis) that the Australian brain resembles most closely those of the Simiidæ and the European fœtus alike. Then as regards the lateral index, the resemblance is, on the whole, with the adult European brain, and with this is associated the type of brain met with in the Cebidæ. It appears, consequently, that the frontal lobe, as defined by the central sulcus, is unusually extensive at the expense of the parietal and occipital lobes (particularly the former). Such extension may be claimed as a character allying the Australian brain to those of the Simiidæ, and also, though less distinctly, to the fœtal brain as met with in Europeans.

(*i*) In the brain (No. 3 of the present series) described by Dr Rolleston (in the *Journal of the Anthropological Institute*, vol. xvii.), the depths of certain sulci are recorded. For instance, in the right hemisphere the central sulcus is shallower than the intraparietal sulcus, and this has been shown by Cunningham and Telford Smith (C. and T.S., p. 310) to constitute a simian characteristic. In the left hemisphere the two sulci are of equal depth. In European (adult) brains the central sulcus is the deeper of the two.

ANOMALIES IN THE SUPRA-INIAL PORTION OF THE OCCIPITAL BONE, RESULTING FROM IRREGULARITIES OF ITS OSSIFICATION, WITH CONSEQUENT VARIATIONS OF THE INTERPARIETAL BONE.

By DAVID HEPBURN, M.D., F.R.S.E., *Professor of Anatomy, University College, Cardiff (University of Wales).*

RECENTLY there was sent to me from Mercury Island, N.Z., a Maori skull, which arrived in a very fragmentary condition. Such restoration as was possible was effected, and then it was found that the occipital bone presented characters of a most unusual kind for an adult specimen. The



FIG. 1.

light which this bone throws upon the dimensions and the mode of ossification of that part of the occipital bone which is usually called the supra-inial portion, is my excuse for putting its characters upon record.

In the current descriptions of the development of the cranium, it is recognised that the tabular part of the occipital bone undergoes ossification partly in cartilage and partly in membrane, and that the transverse fissures which are visible in the fœtal bone mark the junction between these two portions. In a general way these are described as supra-inial and infra-inial, thereby implying that the inion or external occipital protuberance

and the superior curved lines of the adult bone indicate the line of fusion between the membranous and cartilaginous portions of the fœtal bone.

Further, from a variety of observations of its mode of ossification, the supra-inial portion has been accepted as the equivalent of the interparietal bone or *os incæ*, while the number of its primary ossific centres has been variously stated as two, three, or four.

In the *Text-Book of Anatomy*, edited by Cunningham, p. 113, 2nd ed., Professor Arthur Thomson of Oxford gives a useful summary of this point. He there states that "according to Maggi (*Arch. Ital. Biol.*, tome 26, fas. 2, p. 301) they are four in number, of which two, placed on either side of the



FIG. 2.

middle line, appear about the second month. The other pair, placed laterally, are seen about the third month: fusion between these takes place early, but their disposition and arrangement explain the anomalies to which this part of the bone is subject."

The Maori occipital bone, to which I have already referred (fig. 1), presents these four ossific centres as distinct pieces of bone in the adult skull. The two lateral portions are considerably larger than the two central ones, of which that on the right side is slightly larger, and although it was somewhat damaged in transit, yet the sutural lines can be readily distinguished from the lines of fracture. Three longitudinal or antero-posterior sutures separate the four portions from each other, and one transverse suture separates the infra-inial portion of the occipital bone from the four upper portions.

It is worthy of observation that Wormian bones occur in the line of the lambdoidal suture at those points in general relation to its junction with the antero-posterior and transverse sutures in this occipital bone.

From the evidence thus afforded of there being four primary ossific centres concerned in the production of that part of the occipital bone which arises in membrane, it is clear that we may find a variety of conditions in the adult bone intermediate between that here figured and the normal appearance.

In fig. 2 we see the formation of a preinterparietal bone as the result of the fusion of the two central portions with each other, while they have

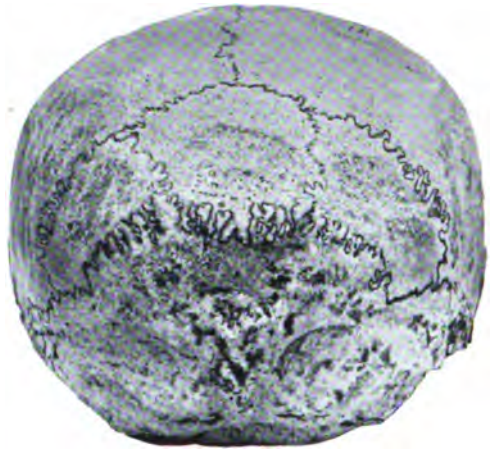


Fig. 3.

remained distinct both from the lateral portions and from the infra-inial portion, which is, however, fused to the lateral portions.

In fig. 3, for which I am indebted to the kindness of Professor Cunningham, the same preinterparietal bone is associated with separation of the lateral portions from the infra-inial portion of the occipital bone.

Fig. 4, on the other hand, presents the result of fusion of three portions (viz. the two central and the left lateral) with each other, and their separation from the infra-inial portion, while the right lateral centre has fused with the infra-inial portion. The fusion of all four centres and their continued separation from the infra-inial portion would present the largest possible form of an interparietal bone. This is shown in fig. 5, for which I have again to thank Professor Cunningham.

Another very interesting feature of the Maori occipital bone (fig. 1) is the evidence which it provides that the terms supra-inial and infra-inial

are not sufficiently precise equivalents for the membranous and cartilaginous sources of the tabular part of the occipital bone. It will be observed that



Fig. 4.

the transverse suture does not correspond to the superior curved lines and the external occipital protuberance (inion). Indeed its course is considerably



Fig. 5.

higher, for it passes above the highest curved line—F. Merkel's "Die linea suprema nuchæ"—and thereby permits us to include in that part of the

occipital bone which ossifies in cartilage not only the area between the highest and the superior curved lines, an area described as the "torus occipitalis transversus," but also a somewhat oval or lozenge-shaped area above the inion.

An examination of the cerebral surface of the bone shows that these parts closely correspond to the commencement of the lateral venous blood sinuses, which, however, also groove the two lateral portions of the interparietal bone as they pass outwards to reach the inferior posterior angles of the parietal bones.

The oval or lozenge-shaped area immediately above the inion is rough and pitted next to that projection, but smooth and slightly concave at a higher level where it is covered by the scalp. This area bears a general resemblance and correspondence to a triangular region occurring on the skulls of the larger anthropoids at the junction between their temporal and transverse occipital crests. In fact the obliteration of the transverse occipital crests with the expansion of that part of the bone on which they occur would fairly account for the production of the "torus occipitalis transversus" of the human skull.

The varying degrees of prominence attained by the external occipital protuberance are probably due to the combined influences of the adjacent muscles, viz. the two complexus muscles below and the two trapezius muscles above, acting in association with the ligamentum nuchæ.

A NOTE ON THE CRURA OF THE DIAPHRAGM AND THE MUSCLE OF TREITZ.

By ALEX. LOW, M.B., *University of Aberdeen.*

IN the following note one would direct special attention to (1) the "decussating" fibres of the crura of the diaphragm, and (2) the muscle of Treitz (musculus suspensorius duodeni).

(1) *Crura of Diaphragm.*—With regard to the muscular fibres of the crura of the diaphragm, the descriptions given, in the standard text-books on anatomy, are misleading in that too much emphasis is placed on the decussation of the innermost fibres of the two crura to form the œsophageal opening. Further, in few cases do the diagrams given correspond to the accompanying descriptions. The result is that the student of anatomy forms a somewhat confused mental picture of the disposition of the crural fibres with regard to the œsophageal opening.

In *Quain's Anatomy*[1] it is stated that "the innermost fibres of the two pillars decussate in front of the aortic opening and pass up on opposite sides of the œsophagus, for which they thus bound an elongated aperture, meeting and again decussating to some extent anteriorly as they join the tendon. In the first decussation the fasciculus derived from the right crus usually passes in front of that from the left, which is much smaller and not unfrequently is altogether wanting."

The more recent English text-books of anatomy adhere to this description—describing the œsophageal opening as being formed by decussating fibres from the two crura.

Testut[2] describes each pillar as giving to the other a decussating bundle; these two bundles intercross in the middle line, the left generally in front of the right, and form the œsophageal opening.

We have carefully observed the disposition of the fibres of the crura of the diaphragm as made out in the course of practical work in the dissecting-room, and the following embodies the results of observations on twenty-five adult subjects—seventeen male and eight female. In addition, dissections of the diaphragm were made in five full-time human fœtuses.

In no case did the left crus send a fasciculus over to bound the right margin of the œsophageal passage. In every case the right crus as traced

[1] Quain, "Elements of Anatomy," vol. ii., part 2, p. 323.

[2] Testut, L., *Traité d'Anatomie Humaine*, quatrième édition, tome 1, p. 848.

upwards gave off a muscular bundle, on an average 10-15 mm. broad, which passed over the front of the aorta, round the left side of the œsophagus, and was inserted into the central tendon rather anterior to the œsophagus.

The fibres of the left crus, in most cases, simply passed up to the central tendon, keeping to the left of the fasciculus from the right crus. In four instances a delicate flat muscular bundle, about 4 mm. broad, was observed starting off from the mesial aspect of the left crus. This small bundle passed over the front of the aorta, above the level of the cœliac axis,

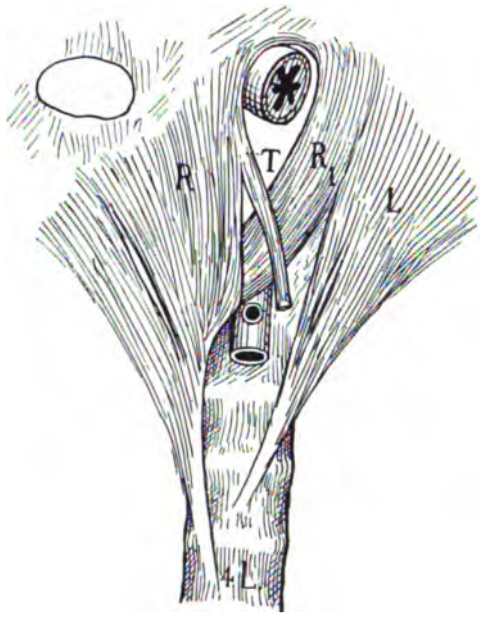


FIG. 1.—Crura in an adult male.

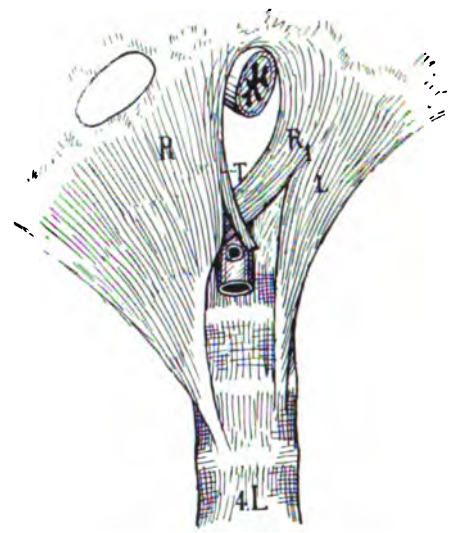


FIG. 2.—Crura in an adult female.

R, right crus; R_1, fasciculus of right crus passing to left of œsophageal passage; L, left crus; T, musculus suspensorius duodeni (muscle of Treitz); X, small muscular fasciculus, sometimes present, passing from the mesial aspect of the left crus and through the fibres of the right crus towards the caval opening.

obliquely through the fibres of the right crus, and eventually could be traced almost to the opening for the inferior vena cava. This could certainly be described as a decussating bundle from the left crus, but it was found in only four of the twenty-five cases examined, and further, it was never continued upwards to help to bound the œsophageal passage on the right side. Hence one may describe the œsophageal passage in the diaphragm as an elongated slit formed by the splitting of the mesial fibres of the right crus.

(2) *The Muscle of Treitz* (musculus suspensorius duodeni). — This

muscle is briefly mentioned in most text-books on anatomy, and all agree in defining it as a fibrous band descending from the left crus of the diaphragm and the tissue round the cœliac axis and attaching itself to the duodeno-jejunal angle. It is said to contain plain muscle tissue. Unfortunately we have been unable to consult Treitz's original description. Testut gives a copy of Treitz's original representation of the muscle, and in it this muscular band is figured as coming from the right crus, although,

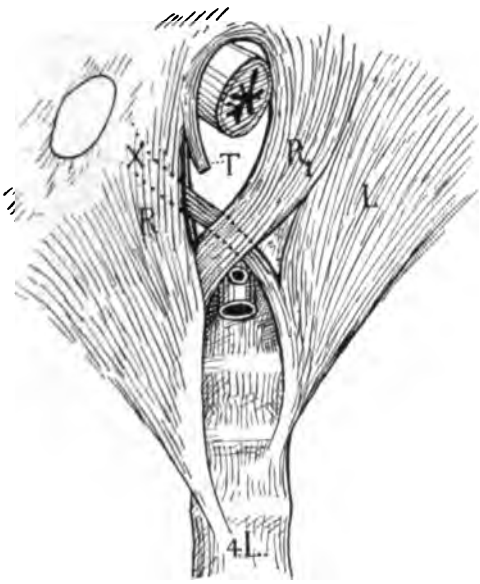


FIG. 3.—Crura in an adult male.

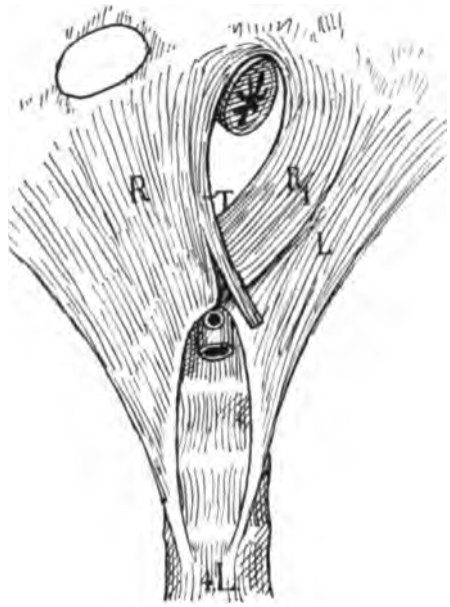


FIG. 4.—Crura in an adult male negro.

curiously, the text describes it as taking origin from the left crus of the diaphragm. We have never seen the muscle of Treitz arising from the left crus, but in seventeen of the adult subjects—twelve males and five females—a small muscular bundle detached itself from the right crus just as it lay against the right margin of the œsophagus. This small muscular bundle—which we take to be the muscle of Treitz—passed downwards and slightly forwards in close relation with the cœliac axis, in front of all other muscular fibres of the crura, to the superior mesenteric artery, under the pancreas, and finally attached itself to the posterior aspect of the upper border of the duodenum near the duodeno-jejunal flexure. Not unfrequently the muscle divided to enclose the cœliac axis—fibres passing on

either side and many being continued into the mesentery.[1] In the fœtus this bundle is readily defined, and histologically contains both striated and plain muscle fibre. Striated muscle fibres can be traced throughout its whole length.

We would direct attention to the four figures given to illustrate this note. They were copied in a diagrammatic fashion from actual specimens. It will be noted that, as a rule, the fibrous arch over the aorta is not a well-marked structure; in the one negro diaphragm dissected, however, this fibrous arch is very strong, and further, both crura have attachments to the fourth lumbar vertebra.

In conclusion, I would thank Professor Reid for the opportunity of making these observations in the Anatomy Department, University of Aberdeen.

[1] Since the above note was read, Mr A. J. Couzens of the West Ham Hospital has kindly directed my attention to C. B. Lockwood's *Hunterian Lectures on the Morbid Anatomy, Pathology, and Treatment of Hernia.* Mr Lockwood describes the suspensory muscle of the duodenum as being inserted into the duodenum, but also running onwards with the superior mesenteric artery into the mesentery. He suggests the name suspensory muscle of duodenum and mesentery.

ON THE REAL NATURE OF THE SO-CALLED "PELVIC FASCIA."

By DOUGLAS E. DERRY, M.B., Ch.B., *Assistant Professor of Anatomy, Government School of Medicine, Cairo, Egypt.*

As long ago as October 1890, Messrs Makins and Anderson (1) published, in the *Journal of Anatomy and Physiology* (vol. xxv.), an account of the subperitoneal and subpleural connective tissue as it occurs in the human subject. The object of the present paper is to extend their description to the pelvis, and to endeavour to show that the complexity of the so-called pelvic fascia may be entirely simplified by the application to this region of the facts elucidated by these writers for those other parts of the body, where subserous connective tissue plays an important part.

It is remarkable that in the many accounts of the pelvic fascia which have been recently published, little or no notice is taken of a tissue which occupies so large a portion of the cavity. As a rule, it is casually referred to as having been removed in order that the fasciæ and muscles hidden beneath it may be studied, while its obvious connections and attachments, both to the walls of the pelvis, and particularly to the viscera, are completely ignored.

Quite recently, however, Professor Melville Paterson (2) has drawn attention to the erroneous accounts of the pelvic fascia given in text-books, and has proposed a new description. This memoir will be found to agree in many respects with his account, but at the same time to give it a new significance by bringing it into line with the facts to which attention was drawn so long since by Messrs Anderson and Makins.

At the outset it is necessary to state that the real "pelvic fascia" (*i.e.* the part which can be truly called "fascia") is that layer which can generally be easily demonstrated, and is, as Professor Paterson says, "strictly parietal." It is taken as an axiom that the pelvic fascia, as such, begins and ends with the walls and floor of the cavity, and has no direct connection with viscera. It is always related to muscles, and where these end it is attached to the periosteum of the neighbouring bone. It is a very strong layer where it covers the obturator internus muscle, and, as has been pointed out by Professor Peter Thompson (5), is composed, at least in some cases, of more than one layer of fascia, the ilio-coccygeal portion of the levator ani muscle being represented by, or continuous with, a thin stratum

when the muscle itself fails to reach the ilio-pectineal line. In any case, the fascia is firmly attached to the bony pelvic wall, and ends abruptly at the anterior margin of the great sciatic notch. The levator ani muscle is also clothed with fascia, as are also the coccygeus muscle and the pyriformis; but in the case of these two latter muscles the fascia is an inconspicuous and often very thin stratum, as is frequently noticed where aponeurotic or tendinous fibres replace the original muscular mass. What really covers these muscles (often in a very definite layer) is the parietal portion of the sub-peritoneal connective tissue (fig. 1), as described by Anderson and Makins (1), and this has often been regarded by former writers as parietal pelvic fascia.

It will be well here to correct a misconception as to the relations of the sacral plexus of nerves and the pelvic blood-vessels to each other. It is commonly stated—Mr R. Atkinson Stoney (4) has recently reiterated it—that these structures are separated by the parietal pelvic fascia, the nerves lying behind the fascia and the vessels in front. This statement has arisen from the belief that the parietal pelvic fascia is prolonged over the pyriformis muscle. As a matter of fact, this muscle has only a very thin sheath, which in the neighbourhood of its attachment to the sacrum is difficult to demonstrate, because the origin of the muscle is composed largely of tendinous fibres with which its sheath blends. Further, whatever sheath exists is attached to the margins of the intervertebral foramina, between which the muscle lies, so that the nerves, in passing out, do not carry a sheath of this fascia with them. They lie upon the muscle and its fascia. Added to this, the blood-vessels are so closely related to the nerve plexus, both in front and behind, that any question of there being a definite layer of fascia between the two is altogether beside the mark. The true pelvic fascia, *i.e.* the fascia covering the obturator internus muscle, does not reach the pyriformis; it ends posteriorly at the anterior margin of the sciatic notch (fig. 3), and its apparent continuation over the pyriformis muscle, which has given rise to the misconception referred to, is due to the attachment to the edges of the sciatic notch of the dense sheath of connective tissue enveloping the outgoing vessels and nerves, which at first sight looks like a prolongation backwards of the fascia covering the obturator internus muscle. This same sheath is prolonged along the vessels which enter or leave the sacral foramina, and then forms a very definite layer over the lower part of the pyriformis muscle. When it is lifted it carries the vessels with it, and they are therefore *in*, and not in front of, this sheath. The nerves lie beneath, and are themselves surrounded by, prolongations of this tissue, but not to anything like the same extent as the blood-vessels. As the vessels pass through the sacral foramina the connective tissue is attached to the margins, and so forms sheaths for the nerves also.

To return now to the more general account of the arrangement of the subperitoneal connective tissue, it will be noticed, as the peritoneum is removed, that the whole cavity is filled with this filmy-looking structure, which extends from the walls of the pelvis to the viscera and to the peritoneum. The ureter and vas deferens will be noticed disappearing in

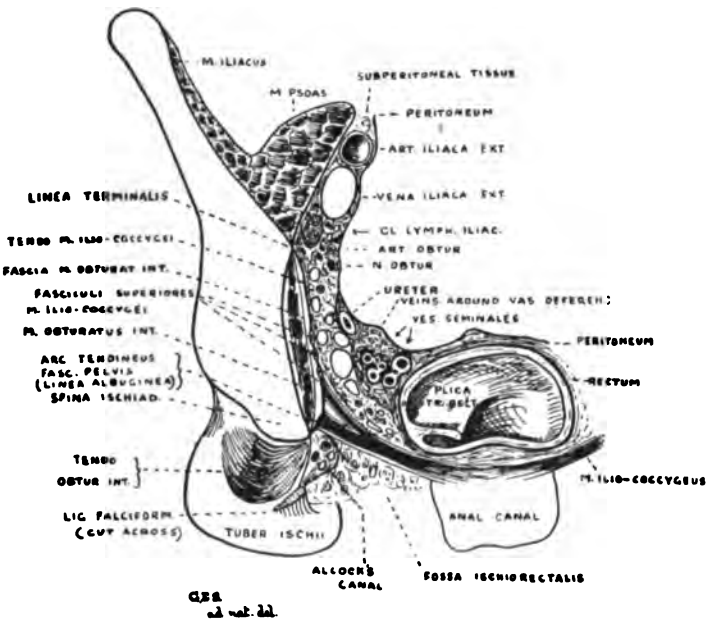


FIG. 1 shows a section made transversely through the pelvis immediately behind the anal canal, so that the lowest part of the rectum is cut through.

The mass of subperitoneal connective tissue enveloping the rectum, vesiculæ seminales, ureter, and blood-vessels is well seen, and its unbroken continuity with the same tissue in the abdominal cavity is demonstrated.

The part of the levator ani muscle shown is the ilio-coccygeal portion, and it is seen to be continuous with the strong aponeurosis overlying the obturator internus muscle, and reaching as high as the pelvic brim (linea terminalis). In this aponeurotic sheet certain scattered fibres of ilio-coccygeus are represented, and marked "Fasciculi superiores." It will be noticed that the obturator internus muscle has its own thin sheath, quite apart from the strong layer referred to which overlies it.

Only the posterior part of vesiculæ seminales is seen in the section. The vas deferens is thus just missed, but its position is denoted in the drawing by the words "Veins around vas deferens," and by the elevation of the peritoneum which it causes.

the midst of it, or, if the subject be a female, the round ligament of the uterus can be traced to the abdominal ring, ensheathed in its whole course by the same tissue. It is sometimes loaded with fat; in other cases this is absent, and it is then more easily broken down; but in all cases, if the fingers are used for this purpose, it will be found that, while the subserous

tissue gives way easily in most directions, it invariably remains firmly attached to the vessels, and particularly those which are passing from the neighbourhood of the sacrum to the rectum, bladder, and vesiculæ seminales or uterus, as the case may be. The tissue in this position forms a dense partition on either side, dividing the anterior portion of the pelvis, with its viscera, from that part which is occupied by the rectum. Not only does it surround the vessels passing to and from the viscera, but it forms sheaths round the ureter and vas deferens, and, where these reach their respective destinations, becomes continuous with the connective tissue capsules enclosing the bladder and vesiculæ seminales.

So far all that has been done is to break down the filmy tissue from its very loose attachment to the walls, and the dissection is thus as nearly unartificial as it is possible for any dissection to be. This is important, because the subsequent attachments to be described are best seen when as little interference with the recent condition as possible is permitted. At this stage some of the subserous tissue is still loosely attached to the pelvic wall, and may be picked off with forceps. As it is lifted, it will be observed to be specially related to the obturator vessels and to attach itself to the margins of the foramen through which these pass in and out of the pelvis. Higher up, it comes into relation with the external iliac vessels, and is here much denser, and from this it passes continuously into the abdomen. This arrangement is well shown in the drawing (fig. 1). Here the pelvis has been cut across transversely, and the section passes immediately behind the anal canal, so that the lowest end of the rectum, where it comes in contact with the vesiculæ seminales, is seen. The mass of blood-vessels running alongside the rectum is here seen to be enclosed with the ureter and vesiculæ seminales (and vas deferens, which just escaped being cut in this section) in a sheath of tissue which is common to them all, as well as to the external iliac vessels and glands and to the obturator vessels and nerve. Round the rectum this tissue is much condensed, and forms a dense sheath which serves to fix the gut loosely to the sacrum and pelvic floor. The vesiculæ seminales are likewise enclosed by special sheaths of the same subserous tissue, and the whole mass forms the partition already referred to which stretches on each side from the sacrum to the viscera.

When the subserous tissue has been completely removed from the pelvic wall, the strong layer of fascia covering the obturator internus muscle is seen. Following this downwards (in the region near the pubis), the finger reaches a point where the fascia is obviously thickened, and at the same place it appears to pass from the wall on to the viscera (fig. 3, C, D). This is generally known as the "white line" (arcus tendineus fasciæ pelvis), and, as it is of some importance in the proper understanding of this region, attention must be specially directed to it here.

Professor Peter Thompson, in the valuable paper already referred to (5), shows clearly that the ilio-coccygeal portion of the levator ani muscle has descended on the pelvic wall, with the result that it now occupies a position about midway across the obturator internus (fig. 3). He describes a dissection of a young kangaroo in which the muscle was found in three parts—one attached to the ilio-pectineal line, a second below the obturator foramen, and the third still lower, under cover of the middle portion. This lowest part was seen, after lifting the middle layer, to be attached to a "white line." He concluded, however, "that this was simply the attachment of

the tendon to the periosteum covering the bone." Now, the interest of this (as he points out) lies in the fact that the corresponding portion of the levator ani in man, which arises at or about the white line, represents the ilio-coccygeus of lower mammals, and he considers that the frequent passage upwards above the white line of the levator ani fibres is an additional indication of its true origin from the ilio-pectineal line. This is undoubtedly the case. In a male Egyptian subject (a drawing of whose pelvic wall is represented in fig. 2), the whole wall was covered by a layer of muscle which was divided fairly distinctly into two parts. The

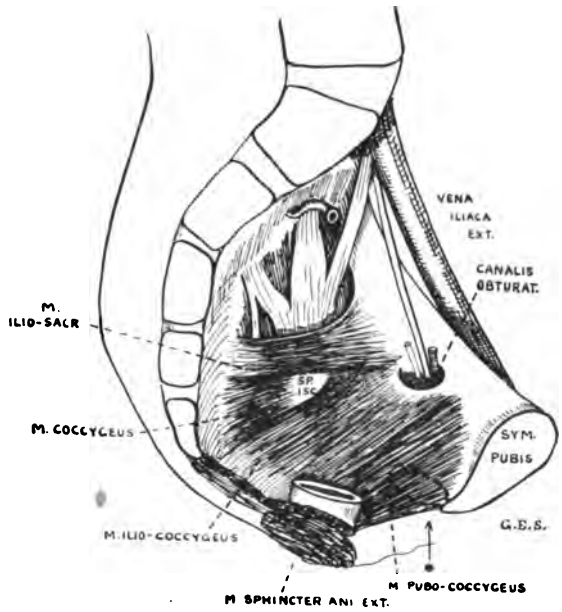


FIG. 2.—The extensive sheet of muscle forming the levator ani in the subject from which this figure has been taken is composed of two parts, pubo-coccygeus and ilio-coccygeus. The latter arises close to the pelvic brim, and passes back under cover of an unusually well-developed ilio-sacralis muscle to the anterior margin of the sciatic notch. In this case the usual definite sheet of "parietal pelvic fascia" was absent, the muscle being merely covered with its own thin fascia, and above this by the subserous tissue—thereby demonstrating that the usual thick layer of parietal fascia is mainly formed from the degenerated portion of the ilio-coccygeus muscle.

The asterisk (*) marks the place of attachment of the prostate and bladder to the lateral pelvic wall. Here the tissue enveloping these viscera is thickened and fixed to the surface of the sheath of the pubo-coccygeus muscle and to the back of the pubis.

anterior portion (pubo-coccygeus) arose from the ascending ramus of the pubis as far out as the obturator foramen, while the posterior portion (ilio-coccygeus) continued this backwards to the anterior margin of the great sciatic notch, in which situation it lay under cover of a well-developed ilio-sacralis muscle.

The ilio-coccygeus arose by tendinous fibres from the side wall of the pelvis as high up as the foramen for the obturator vessels and nerve, but short of the ilio-pectineal line. It thus represented the first or highest attachment seen in the kangaroo. This seems to be uncommon in the human subject, but the lower

attachment to the obturator fascia a short distance above the "white line" is frequently seen, and has given rise to the name, arcus tendineus musculi levatoris ani. This is shown in Spalteholz's *Handatlas der Anatomie des Menschen* (3). It corresponds to the middle division described by Professor Thompson in the kangaroo. But, in addition to these fibres, there are others *which arise from the white line itself*, so that all the three attachments described by Professor Thompson in the case of the kangaroo may be found in the human subject. The writer has before him two pelves, a male and a female, in both of which, with slight variations, the following condition occurs. The pubo-coccygeus is a definite, and in the female case distinct, bundle of muscular fibres, arising from the back of the body and ascending ramus of the pubis, as far as the foramen for the obturator vessels and nerve. It passes backwards on the side of the rectum, to be inserted into the ano-coccygeal ligament and tip of the coccyx, the former attachment being the principal one. This portion of the muscle is crossed by a strong band of fibrous tissue (white line) coming from the lower part of the back of the pubis. This band is loosely attached to the muscle in passing, but no fibres take origin from it. The ilio-coccygeus, on the other hand, has two origins in both subjects (compare fig. 1). Some of the fibres arise from, or are continuous with, a sheet of fascia which in this instance is distinctly aponeurotic in character, reaching as high as the level of the upper margin of the obturator foramen (A and E in fig. 3). This is quite distinct from the layer forming the true muscle-sheath of the obturator internus (see fig. 1, *Fascia m. obturat. int.* and *Tendo m. ilio-coccygei*). But there is a second origin, extremely well marked in the female subject, weaker but quite distinct in the male specimen, which arises *directly* from the white line (B, fig. 3; compare also fig. 1, *Arcus tendineus fasc. pelvis*), and uniting with the fibres from above, passes downwards and backwards to the coccyx. These latter fibres arising directly from the white line would seem to correspond to the third or lowest division found in the kangaroo's pelvis, in which (in Professor Thompson's own words) "it was seen to have a remarkable tendinous origin, . . . which appeared to come from a 'white line.'" Professor Thompson, however, does not consider that this was the representative of the "white line" of human anatomy, and says that "it was clear that this was simply the attachment of the tendon to the periosteum covering the bone." In the human subject, however, there are only two bony points on the lateral pelvic wall available for muscular attachment in such a position as that occupied by the levator ani, and these are the back of the pubis and the ischial spine. It is between these two points that the white line is found, its strongest attachment being from the first-named bone; and nothing, therefore, is more natural than to consider it, under such circumstances, as the tendon of this (ilio-coccygeal) part of the muscle.

In fig. 3, the disposition of the "white line" and its relation to the two different parts of the levator ani muscle are clearly seen. The drawing was made from the female subject described above, who was a Sudanese negress. But in another female—an Egyptian—dissected during the writing of this paper, an almost similar condition was present. In both of these cases the ilio-coccygeus is an extremely strong sheet, and when pulled upon, in the case of the negress, imparts a considerable amount of movement to the coccyx. The additional attachment of the "white line" to the pelvic wall near the obturator foramen (as shown in fig. 3, A E) is present in both of the female subjects, and is not without interest, seeing that in these same two cases the ilio-coccygeus is exceptionally large and arises in both directly from the "white line." The suggestion made by Professor Thompson (following Luschka) that the muscular fibres are only attached to the white line by connective tissue, is thus

disproved by the condition found in these two specimens, in which the "white line" is evidently the tendon of the muscle.

It is interesting to note, that in the case of the male subject, a drawing of whose lateral pelvic wall is represented in fig. 2, where the two parts of levator ani muscle covered the whole of obturator internus, no distinct layer of pelvic fascia, such as is usually found in this situation, was present. This is very suggestive of the muscular derivation of the parietal pelvic fascia, and it is further borne out by the condition existing in the Sudanese negress, where nothing but a thin arachnoid tissue was found in the area labelled "Fascia pelvis" (fig. 3) continuing the white line upward and backward to the anterior margin of the sciatic notch. This is shown in fig. 3. The underlying obturator internus muscle was covered in this

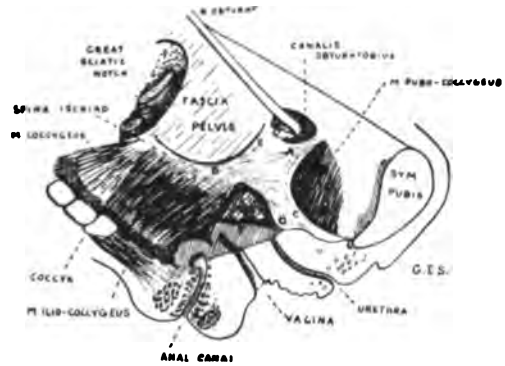


FIG. 3.—The side wall of the pelvis of a Sudanese negress, as seen after the removal of the viscera. In this case the "white line" is an extremely strong and conspicuous band, which is attached to the pubis and to the ischial spine as usual, but has also a third aponeurotic attachment at A and E, to the upper part of the pelvic wall. The most anterior part C overlies the pubo-coccygeus muscle, but has no definite attachment to it; but this same portion, when followed back to A, is seen to be continuous with the aponeurotic portion A E. This fascia (B A E) covers a sheet of muscle (part of the ilio-coccygeus) reaching as high as the obturator foramen, which is hidden in the drawing. The larger part of the ilio-coccygeus arose lower down on the pelvic wall, directly from the part of the "white line" marked B, the most posterior fibres of the muscle being attached to the bone near the ischial spine. Above B the obturator internus muscle is covered, in the area labelled "Fascia pelvis," by a thin prolongation of B E as far as the anterior margin of sciatic notch. D is placed upon the cut edge of the line of fixation of the viscera to the "white line." Here the subperitoneal connective tissue enveloping the bladder and vesical plexus of veins blends with it. The veins are seen just above F.

locality by the only really definite layer of fascia found on the pelvic wall, and this, as already said, was more like the rest of the subperitoneal tissue enveloping the vessels, etc., than the strong layer of fascia so generally met with here. In fig. 3 it is denoted as "Fascia pelvis," and is seen to lie behind the strongly marked "white line" (E B), which here serves the purpose of a tendon of origin for the ilio-coccygeus muscle.

This, then, may help to explain the origin of the "white line" in man, which is at times only feebly represented. Thompson quotes Kollmann as saying "that it is possible that some of the bundles of levator ani in man may have been converted into a tendinous arch—the white line; and he is of opinion that the differences in its development may possibly be due to the influences of pressure and pulling."

The "white line," even in those cases where it is poorly developed, usually occupies a very definite position, a line joining the spine of the ischium to the lower margin of the body of the pubis, and it is undoubtedly a tendon of attachment of the ilio-coccygeus to these bony points. In proportion as the origin of the ilio-coccygeus is placed above this line—either in man or other mammals of any Order—the white line becomes correspondingly feeble; and it is best developed in those cases in which the greater part or the whole of the ilio-coccygeus has slipped down to the level of the line joining the ischial spine to the lower border of the pubis. It is clearly the tendon of the ilio-coccygeus alone, and has no connection with the pubo-coccygeus, on the surface of which it lies. It is situated in the angle between the lateral pelvic wall and the viscera (bladder, prostate, etc.), and acts as a direct bond of union between the two; *i.e.* it is that part of the pelvic wall to which the subperitoneal tissue surrounding prostate and bladder becomes attached (fig. 3, CD). The rectum is not affected by it, as Professor Paterson has shown. Its attachment to the back of the pubis provides a place of fixation for the ligaments of the prostate and bladder, which are formed by a condensation of subperitoneal tissue (fig. 3, D). Anteriorly, these ligaments are usually well marked, but as they are traced backwards they become weaker and their attachment to the "white line" is more indistinct, and in most cases fades away towards the ischial spine (see fig. 3). When there is no white line (fig. 2), the ligaments of the bladder and prostate become fixed to the surface of the sheath of the pubo-coccygeus, in the situation where the anterior part of the "white line" is found in other cases (fig. 2, *).

If the finger is following this line of attachment backwards in the angle named, it sinks deeper as it goes, and it will be noticed that the floor becomes less fibrous. Without much effort in most cases the finger can be made to pass through the cellular tissue in this region, *i.e.* in the neighbourhood of the ischial spine, and if it is pushed onwards it will arrive on the pelvic floor, behind the rectum, and beneath the partition which is produced by the mass of blood-vessels, nerves, etc., wrapped in connective tissue, passing from the sacral region to the organs. In other words, the "white line" is continuous on the visceral side with the subperitoneal tissue enveloping the vessels, and if these are followed to their destination, it will be found that the organs they supply are likewise invested by the same tissue. If the lateral true ligament (fig. 3, D) is followed directly on to the bladder, the same relations are discovered. The tissue attached to the "white line" lies immediately over the vesical plexus of veins, which in the female are often very large (see fig. 3, just above F). In such a case it is easy to follow the course of the veins along the side of the bladder and directly backwards into the internal iliac veins, covered in their whole course by subperitoneal connective tissue, and this same tissue can be traced in direct continuity with the lateral true ligament over the bladder itself. This continuity is well seen in fig. 1 in the more posterior portion of the course of the vessels, that is, in the vicinity of the rectum.

Here, then, lies the explanation of the arrangement of the so-called "visceral pelvic fascia." The writer's investigations lend support to Professor Paterson's suggestion that the term "visceral pelvic fascia" should be altogether dropped, but it is for a different reason. As he has attempted to show in this paper, the viscera are all enveloped in subperitoneal connective tissue which is, as Messrs Anderson and Makins (1) point out, mesoblastic in origin. The viscera, therefore, are simply

invested by the remains, in this mesenchymatous form, of the tissue in which they originally developed, and the same applies to the vessels which supply them (fig. 1). This tissue is condensed in places to form definite ensheathing layers, particularly in the neighbourhood of the prostate and vesiculæ seminales in the male, and vagina and lower part of uterus in the female. But any attempt to give definiteness to such layers is not only artificial, but makes the description unnecessarily complicated and confusing, for the simple reason that these layers, though well marked in the regions named, and also around the rectum, pass gradually into the general mass of subperitoneal tissue which fills the whole pelvic cavity, and are then no longer traceable. Further, though this tissue has definite and more fibrous attachments in places, which might be dignified with the name of fascia, it is quite distinct from that layer generally known as parietal pelvic fascia, which, from the evidence adduced in this communication, is probably aponeurotic in origin, and is always related to muscles.

The "suspensory ligament" described by Professor Paterson as arising in the neighbourhood of the ischial spine is nothing more than the attachment in this position, *i.e.* to the most posterior part of the "white line," of the subperitoneal connective tissue which here envelops the vessels passing to the viscera, including the ureter and vas deferens. One of his own illustrations (fig. 2) shows the continuity of this tissue with the dense layer surrounding the rectum, and it is in this region that the separation of the subperitoneal tissue into visceral and parietal laminæ, as shown by Anderson and Makins (1), is most distinctly seen. The so-called rectal channel is thus formed, the parietal layer of subserous tissue forming the walls of the channel and the visceral layer investing the rectum itself. An additional proof of the true subserous origin of these layers may be seen in the fact that the lowest portion of the recto-vesical pouch of peritoneum in the male, and recto-uterine or pouch of Douglas in the female, is tied firmly to the underlying tissue, which in the one sex forms a sheath for the seminal vesicles, and in the other clothes the back of the vagina. The failure to recognise the true origin of this tissue has thus given rise to many and varied accounts of the pelvic fascia, which are due not so much to incorrectness of description as to misinterpretation of the facts.

The writer is not alone in his conclusions as to the origin of the so-called visceral pelvic fascia. In his memoir (5), to which such frequent reference has been made in the preceding pages, Professor Thompson says: "We know that a fibrous sheath envelops the obliterated hypogastric artery, and the vessels supplying the bladder, uterus, vagina, and rectum, and it may be that the supporting layers of the pelvic fascia are primarily derived from this by lateral extension on to the fascia covering the upper

surface of the levator ani. . . . . In the orang-utan the visceral layer of the pelvic fascia, at least in its hinder part, is double, and some of the vessels derived from the hypogastric trunk are situated between the two layers." What is true for the orang is also true for the chimpanzee. In a female specimen of the latter anthropoid, dissected by the writer, the conditions found closely resembled those ordinarily existing in human pelves, in cases where the levator ani is small and the "white line" not conspicuous. In this case, after removal of the subperitoneal tissue from between the bladder and pelvic wall, the usual thickening in the ordinary position of the "white line" was well seen, and it formed here, as in the human subject, the anterior and lateral true ligaments of the bladder. Traced backwards, it divided, one part remaining as a thickening of the pelvic fascia on the wall, carried towards the ischial spine, the other blending with the general mass of subperitoneal tissue enveloping the vessels, etc. This arrangement, as already said, resembles that commonly seen in the human subject, and, though it might not be dignified with the name of "white line," is none the less homologous with that structure.

In this communication the writer has confined his attention to the conditions found in the human subject, because he has found in man such a complete series of gradational forms that it has not been necessary to make use of comparative data. During the course of the work the condition of the pelvic muscles and fasciæ has been studied in specimens of *Tarsius* (given by Dr Charles Hose to the Cairo School of Medicine), a large series of Prosimiæ and Apes (given by Captain Flower, of the Giza Zoological Gardens), and one of the chimpanzees presented to the School by Professor Sherrington of Liverpool.

The writer owes to Professor G. Elliot Smith, of the Cairo School of Medicine, his best thanks for the drawings he has made specially for this paper, and for his constant interest in the work.

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PELVIC MUSCLES AND FASCIÆ.

By Douglas E. Derry, M.B., Ch.B., *Assistant Professor of Anatomy, Government School of Medicine, Cairo, Egypt.*

The original object of the work upon which this communication is based was to endeavour to give a clearer account of the pelvic fascia than that generally adopted, and the results of that work are published in the present number of the *Journal of Anatomy and Physiology*. I do not propose, therefore, to take up time so much with a discussion of that side of the question, as with another, viz. that of the pelvic muscles. At the outset of my work I realised that a proper understanding of the fascia was impossible without an equally clear understanding of the muscles so closely associated with it, and the present paper is an attempt to elucidate the facts already made out by other observers, and to confirm them by additional evidence. This evidence has been obtained by the dissection of a number of Egyptian and Negro pelves, as well as of those of a large series of Primates; but as the human specimens afford all the data upon which my conclusions are based, it will not be necessary to draw to any great extent upon the other sources of information.

I shall not discuss here the work of other investigators whose researches have been of such great service to me in the course of my own labours, but I should like particularly to mention the names of Professor Peter Thompson and Dr Arthur Keith, whose studies, from the side of comparative anatomy and of morphology respectively, I have found most valuable.

The muscles mentioned above, which are chiefly concerned in this investigation, are those of the pelvic diaphragm—the levatores ani. As is well known, the levator ani muscle in reality consists of two distinct parts, the pubo-coccygeus and the ilio-coccygeus, and these two portions are the representatives in the human subject of two of the tail-muscles of lower animals. It is under these names that the muscle will be referred to in this paper.

The inference drawn by Professor Peter Thompson from studies in comparative anatomy, that the so-called parietal pelvic fascia in man is mainly composed of the degenerated upper part of the ilio-coccygeus, is fully confirmed by many of my specimens, in which the fleshy fibres of the ilio-coccygeus actually reach up to the neighbourhood of the ilio-pectineal line and take the place of the parietal fascia (fig. 1).

The so-called "white line" is much reduced in such cases, and is only present as a strong cord in those instances where the chief mass of the *muscular* part of the ilio-coccygeus does not extend above the level of a line drawn between the ischial spine and the lower border of the symphysis pubis.

In such cases the "white line" is the tendon of the ilio-coccygeus muscle, and it passes over the surface of the pubo-coccygeus without any attachment to the last-named muscle, in order to give the former an origin from the os pubis. When this tendon is absent, the white line exists as a simple condensation of connective tissue around certain vessels, serving at

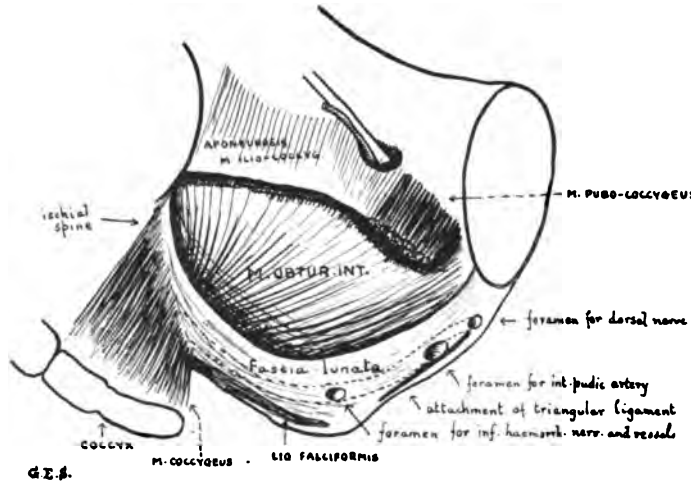


FIG. 1.—Mesial aspect of part of the left side of the pelvis of a Negro, to show the fascia lunata. Alcock's canal is shown by means of dotted lines.

the same time to fix the neighbouring viscera to the walls or floor of the pelvis. In this way the pubo-prostatic and lateral true ligaments of the bladder are produced. Contrary to the opinions expressed by Professors Macalister and Le Double, that the levator ani is not subject to variation, I have found it to be, perhaps, the most variable muscle in the body.

The *ilio-coccygeus* may be a thick sheet of muscle lining almost the whole vertical extent of the pelvic wall behind the canal for the obturator vessels and nerve, or it may be wholly transformed into a thin sheet of transparent non-muscular membrane, and every intermediate condition can be found between these two extremes. Its attachments, both above and below, the direction of its fibres, their length and their relations to the pubo-coccygeus and coccygeus, are all subject to a wide range of variation.

The *pubo-coccygeus*, though less variable than the ilio-coccygeus, is by no means constant. Its pubic origin is fairly so, but it may extend back as far as, or in other cases beyond, the foramen for the obturator nerve and vessels. It may be overlapped by, or on the same plane as, the ilio-coccygeus. In many cases it is inserted largely into the mesial perineal raphe, but I have seen instances where it is inserted wholly into the perianal tissues and is a pure levator ani.

The so-called parietal pelvic fascia of most human subjects includes three entirely distinct structures—(*a*) the degenerated aponeurotic remains of the upper part of the ilio-coccygeus; (*b*) the delicate sheath of the obturator internus muscle; and (*c*) a very dense crescentic mass of fibrous tissue which covers in the lowest, most ventral portion of the obturator internus muscle (fig. 1). This structure, which I have called the *fascia lunata*, is actually that part of the obturator fascia which forms the outer wall of the ischio-rectal fossa, and encloses the pudic vessels and nerve in a sheath usually known as Alcock's canal. It has very definite attachments forming a great arcuate band, the extremities of which are the ischial spine posteriorly, and the lower border of the symphysis pubis in front, while its lower edge is continuous with the falciform process of the great sciatic ligament. Further forward on the pubic arch it comes in contact with the triangular ligament. It thus bridges over the space between the great sciatic ligament and spine of ischium, and the pudic vessels and nerve returning through this arch become enclosed in its substance. If traced beyond the spine, it is seen to become continuous with the sheath of the coccygeus muscle. Its thick upper margin is continuous with the exceedingly delicate sheath of obturator internus muscle, and at this same spot the levator ani muscle, in its passage towards the rectum, gets attachment to it through its own sheath, thus forming the apex of the ischio-rectal fossa (fig. 2). In other words, if the levator ani muscle be separated from the pelvic wall at its origin and pulled inwards, the finger can be passed down, traversing the filmy sheath of obturator internus, until it arrives at a point between the fascia lunata and the muscle, Alcock's canal and its contained vessels then lying to the inside.

This fascia is equally well developed in the apes, where in certain cases, as that of the baboon, it exactly corresponds with the lowest ventral edge of pubo-coccygeus muscle, whose sheath becomes continuous with this strong fascia. In these animals, too, its continuity over the coccygeus is also well seen, as also the manner in which the pudic vessels and nerve reenter the pelvis under cover of the bridge it forms with the ischial spine.

In man, the assumption of the erect attitude, and the consequent alteration in the direction of the fibres of the pubo- and ilio-coccygeus

muscles, has led to a sliding forward and downward of the muscle, across the fascia lunata, thus producing a fossa, the ischio-rectal, which has no existence in the apes referred to.

This demonstration of the relation of the pudic vessels and nerve to the fascia lunata in their whole extent shows that the ordinary method of describing these structures as perforating the base of the triangular

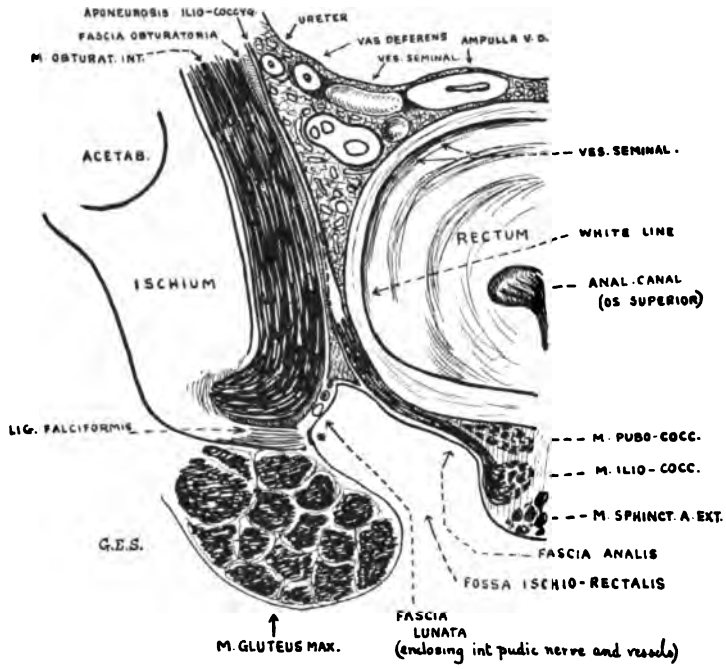


FIG. 2.—Part of a coronal section made by Dr Elliot Smith through the pelvis of an Egyptian Fellah immediately behind the bladder.

It shows the walls of the ischio-rectal fossa and the connections of the *fascia lunata*. At the place marked by the asterisk (*) the processus falciformis of the great sciatic ligament becomes continuous with both the lunate fascia and the sheath of the gluteus maximus. Dorsally, the lunate fascia is joined to the sheaths of both the obturator internus and the levator ani, the latter of which forms the anal fascia.

ligament is erroneous, and it becomes more than doubtful whether any such structure as the superior or deep layer of the triangular ligament exists.

I shall not at present take up any further time in discussing the so-called visceral pelvic fascia. As already mentioned, this is fully dealt with in my paper on that subject; but the description I have just given of

the pelvic muscles is a necessary introduction to the understanding of the fascia.

Apart from the fact that these notes indicate the true nature of the pelvic muscles and fasciæ, it has been found in practice that the ideas here put forth greatly simplify the anatomy of the pelvis for teaching purposes, and make intelligible to even the dullest student the description of a region which has hitherto presented great difficulties both to students and teachers.

In conclusion, I wish to tender to Professor Elliot Smith, of the Cairo School of Medicine, my grateful thanks for the interest he has shown in the work, and also for the drawings he has so kindly made to illustrate it, without which a proper description of this region would have been impossible.

THE FASCIA OF THE PELVIS.

By JOHN CAMERON, M.D., D.Sc., F.R.S.E., *Senior Demonstrator of Anatomy, University of Manchester.*

THE pelvic fascia has been so fully described by Berry Hart (2), Holl (3), Thompson (8), Stoney (7), and Paterson (5) that at first sight it seems unnecessary to make any further contribution to the literature of this subject. It must be admitted, however, that the description in text-books is still far from satisfactory. The greater part of the misconception which at present prevails regarding this structure is due to the fact that it is usually described as a special formation, there being no clear statement as to why the pelvic fascia should be in existence at all. The main object of this communication is to direct attention to the importance of recognising the morphology of the pelvic fascia, and thereby emphasising its true significance. Keith (4) is the only authority, so far as can be ascertained, who has treated the fasciæ throughout the body from the morphological standpoint. If one studies the fascial layers in any region, it will be readily recognised that, in those situations where they are at all well marked, they represent, in part at least, the sheaths of certain muscles. What is commonly described as the parietal pelvic fascia will therefore be found to consist of the sheaths covering the pelvic surfaces of the following muscles:—

1. The obturator internus.
2. The compressor urethræ.
3. The pyriformis.

The marginal attachments of the fascia covering the pelvic surface of the obturator internus thus follow more or less intimately the various borders of that muscle. In the case of the upper border, for example, the obliquity of the line of attachment to the pelvic surface of the os innominatum is due to the fact that the upper margin of the obturator internus is also very oblique in direction. Seeing that this attachment is governed by the relative degree of development of the muscle, it may be noted that the posterior inch or so does not necessarily reach as high as the iliopectineal line unless the corresponding part of the muscle margin also reaches to that level. Opposite the opening in the obturator membrane the fascia again retains its close association with the muscle fibres, and therefore folds over the upper border to blend with the obturator membrane.

The latter structure is nothing more or less than the conjoint fascial sheath for the posterior surface of the obturator externus and the anterior surface of the obturator internus. The deficiency in the upper border of the membrane is therefore simply due to the fact that the corresponding borders of these muscles do not reach to the upper margin of the foramen. On the posterior surface of the body of the pubis the upper border of the obturator internus descends very obliquely downwards and inwards towards the lower end of the symphysis, and the upper attachment of the fascia follows a like course. The inferior attachments of this fascia follow those

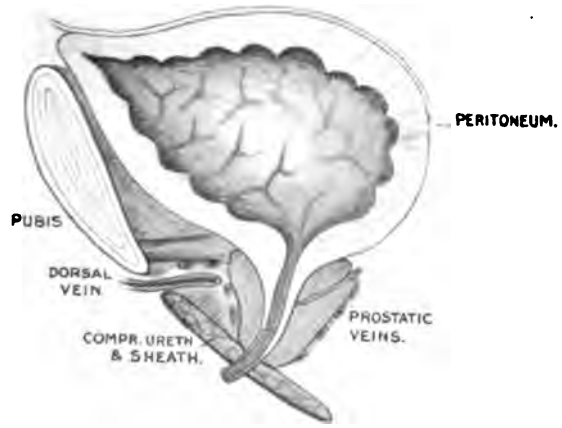


FIG. 1.—The relation of the prostate and dorsal vein to the compressor urethræ sheath. This as well as the succeeding figures have been drawn from specimens fixed with formalin.

of the muscle along the margin of the pubic arch and great sacro-sciatic ligament, while posteriorly the fascial and muscular margins again correspond along the great sciatic notch and base of ischial spine. Between the latter point and the great sacro-sciatic ligament the sheath is prolonged backwards on the tendon of the muscle.

The fascial sheaths covering the upper or pelvic and lower or perineal surfaces of the compressor urethræ constitute the upper and lower layers of the triangular ligament. A proper appreciation of this fact will, however, be prevented until the erroneous accounts of the origin of this muscle undergo modification. A careful dissection shows that the said origin is much more extensive than is usually imagined. The

muscular attachment to the pubic arch will be found to correspond in extent with that of its fascial sheaths, *i.e.* the triangular ligaments. This appearance is well figured by Keith.[1] These sheaths therefore meet round the posterior margin of the muscle to form the so-called base of the triangular ligament, while similarly they meet round the anterior margin to form the transverse perineal ligament (fig. 1). The latter is therefore not entirely formed by the superficial layer of the triangular ligament, as generally described. The meeting of the superficial and deep sheaths over the anterior muscle margin gives the rounded character to this ligament. From this description it is obvious that the dorsal vein of the penis cannot lie, as commonly supposed, between the two layers of the triangular ligament: it is quite outside the

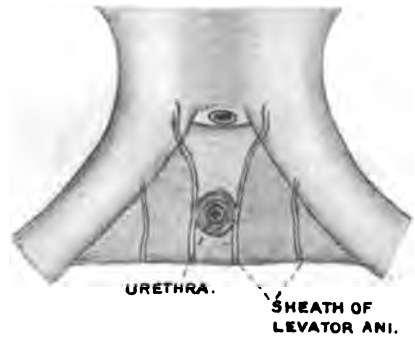


FIG. 2.—The fascia on the pelvic surface of the compressor urethræ.

muscle sheath (fig. 1). The sheath of the vein is attached all round the gap between the transverse perineal and subpubic ligaments, an arrangement which prevents the passage of extravasated urine at this point. If the fascia on the pelvic surface of the compressor urethræ be studied, it will be seen that it is divided into certain regions (figs. 2 and 3). The portion next to the pubic arch is separated from the anal fascia by a slight angular interval which is occupied by connective tissue (fig. 3). To the inner side of this area the *levator ani* sheath is firmly fused with this fascia as far as the point where the former bends round the inner margin of the levator ani to become continuous with the fascia on its upper surface (forming the rounded pubo-prostatic ligament). The line along which the fascia of the levator ani leaves the fascia of the compressor urethræ is indicated in fig. 2. At this point the results of my dissections differ from

[1] *Op. cit.*, p. 165.

the commonly accepted description of the fascia on the pelvic surface of the compressor urethræ It is inconvenient to group this layer under the heading of parietal pelvic fascia, seeing that the use of this term veils its true significance as a muscle sheath. Moreover, this parietal fascia is described as being reflected from the surface of the compressor urethræ by the urethra—thus leaving that part of the muscle in the middle line devoid of fascia. Now, as a matter of fact, those portions of the pelvic surface of this muscle in front of and behind the urethra have a continuous fascial covering from side to side, but opposite the urethra the apex of the prostate rests directly on the muscle, at which point the sheaths of the gland and muscle blend. Note again that the line of the reflection is produced by the fascial sheath

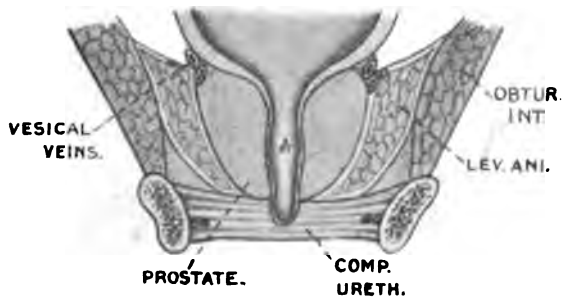


Fig 3.—The relation of the levator ani sheath to the prostate and to the compressor urethræ sheath.

of the levator ani leaving the surface of the *compressor urethræ* fascia, and not the surface of the muscle tissue itself.

The title *compressor urethræ* is an obvious misnomer. Only the circular fibres which immediately surround the urethra may be said to constitute the compressor. The remainder of the muscle would be better classed as part of the pelvic diaphragm along with the coccygeus and levator ani. Fig. 3 shows the close relationship which the latter muscle bears to the compressor urethræ.

The pyriformis fascia is simply part of the sheath of that muscle. The sacral plexus will be found more or less embedded in the pyriformis, so that it is also enclosed within the sheath. This fascia is quite a distinct morphological element from the obturator fascia. The two are not in direct continuity.

The description of the so-called visceral pelvic fascia in text-books is

somewhat complicated, the splitting into vesical, recto-vesical, and rectal layers being, to say the least, very difficult to recognise. Here, above all, the confusion has arisen from a failure to appreciate the full morphological significance of this structure. It is essentially the fascia covering the

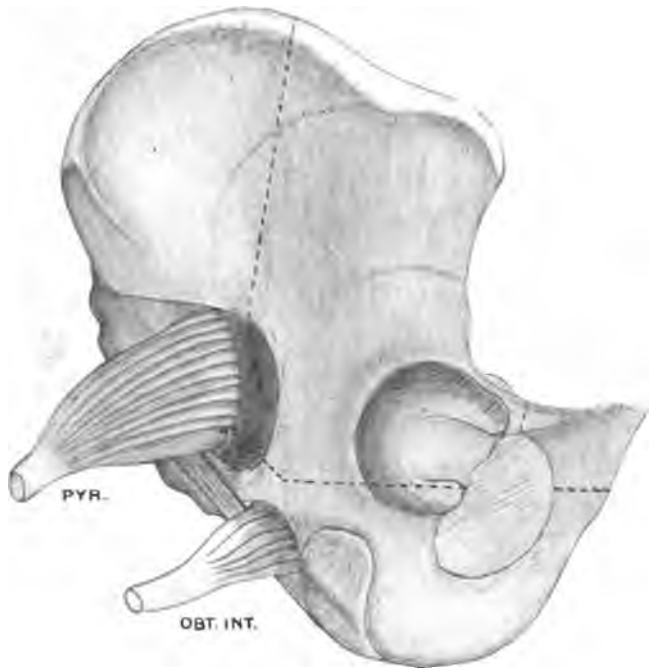


FIG. 4.—Lines of incision to expose the pelvic fascia.

pelvic surface of the levator ani and coccygeus muscles, associated with fascia from other sources, to be described presently.

Dissection.—The author has improvised a method of exposing the various arrangements of the pelvic fascia which may be found of service. The psoas, iliacus, and external iliac vessels are removed. The pelvic peritoneum is next carefully detached, and the internal iliac vessels and ureter exposed. On separating the latter from the lateral pelvic wall, it will be found that they are firmly bound to the surface of the innominate bone by a mass of connective tissue. The importance of this bond of union will be appreciated subsequently. The pubis is

sawn through horizontally one-half to three-quarters of an inch from its lower end, the acetabulum and ischium being similarly treated in the same plane as far back as the base of the ischial spine, which the saw should reach a little above its mid-point (fig. 4). A short cut from the upper margin of the root of the spine is next made to join the posterior end of the previous one. The ilium is sawn through vertically, beginning about the middle of the crest, and ending in the great sciatic notch. This last incision may be varied greatly. The upper part of the symphysial fibro-cartilage is divided, and the piece of bone thus marked out is dissected off

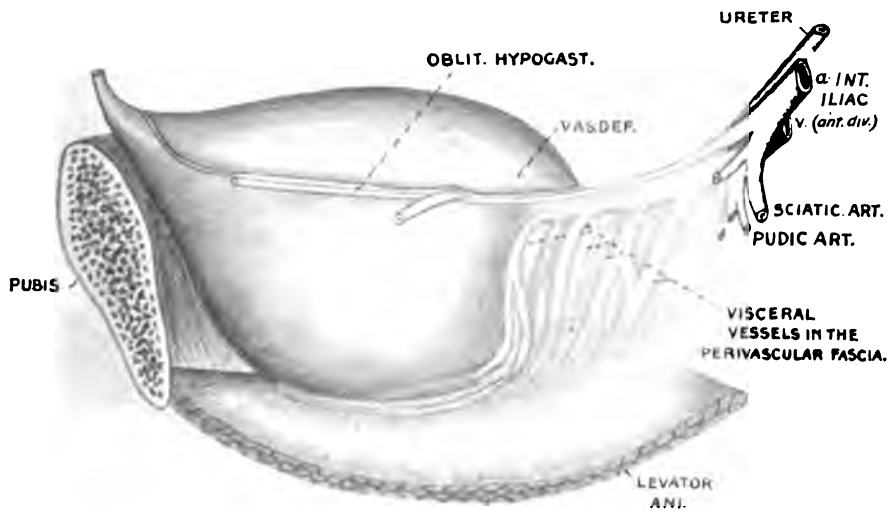


FIG. 5.—Adult male bladder from the left side, showing its fascial mesentery.

from the obturator internus, the latter muscle being then cut through horizontally in the plane of the first incision. This will be found to be just above the line of origin of the levator ani and coccygeus (see figs. 9 and 10).

The Male Pelvis.—It is most convenient to devote attention first of all to the internal iliac vessels. The anterior divisions, along with their visceral branches, are found to be bound together by a dense connective tissue—the perivascular sheaths. The resultant compact mass will be found to lie in a more or less vertical plane, and to possess fairly definite borders of attachment. Thus it was previously shown to be firmly united by its *external border* and antero-external surface to the innominate bone close to the sciatic notch, and lower down to the obturator fascia. From

this origin the mass passes forwards and inwards along with the vessels to blend *internally* with the posterior part of the lateral aspect and base of the bladder (fig. 5), the seminal vesicles, and the lower part of the rectum. The perivascular fascia is thus firmly blended with the capsules of the bladder, rectum, seminal vesicle, and terminal part of the vas deferens. This fascia is continuous from side to side between the bladder and rectum, and evidently forms the so-called "recto-vesical layer" of the visceral pelvic fascia. The *upper margin* is free, and contains the anterior division of the internal iliac artery with its continuation the

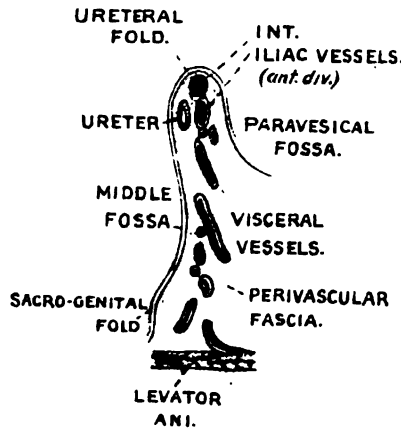


FIG. 6. — Vertical section of ureteral fold, middle fossa and sacro-genital fold.

obliterated hypogastric. Note particularly that the ureter is bound down by fibrous tissue first to the upper border, and then, as it approaches the bladder, to the posterior aspect of this mass (fig. 5). The *lower margin* is intimately blended with the sheath on the pelvic surface of the levator ani. It may now be recognised that we have here a sort of fascial mesentery which must constitute an effective support to the pelvic viscera. The fascia tends to become denser and stronger as it is traced downwards towards the pelvic floor. The latter part corresponds to the suspensory ligament of the genito-urinary organs recently described by Paterson (5). This observer has made a comparative study of the latter structure in mammals, and has been much struck both with its constant presence and its prominence in all the types examined.

The pelvic peritoneum is moulded round the free upper margin of this fascial mesentery, forming the ureteral fold. It is therefore obvious, from the foregoing description, that the anterior divisions of the internal iliac vessels must likewise be in close relation to this fold. The peritoneum clothes slightly the antero-external aspect of the fascial mesentery in passing downwards into the paravesical fossa. Posteriorly the peritoneal covering is very extensive in the male, the greater part of this aspect being so invested (fig. 6). The aggregation of tissue which gives rise to the

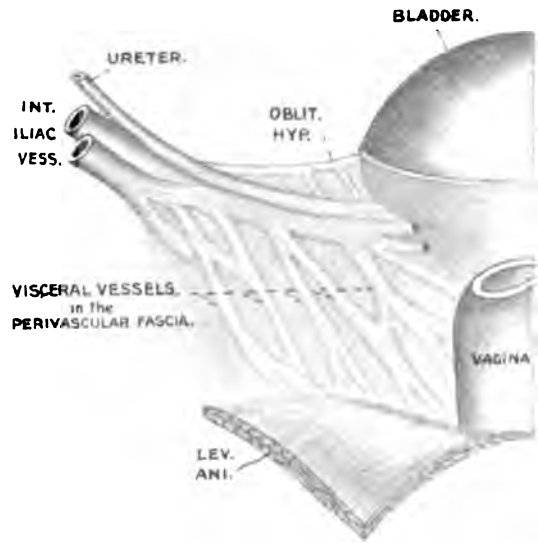


FIG. 7.—Viscera of female pelvis, showing the relation of the base of the bladder to the visceral vessels and perivascular fascia.

genital fold (Dixon (1)) lies on the posterior aspect of the perivascular mass. These sacro-genital fibres are therefore associated not only with the sacrum but also with the lateral pelvic wall, and they pass forwards and inwards along with the vessels to the base of the bladder and seminal vesicle. The floor of the middle fossa (Birmingham and Dixon) is obviously formed by the peritoneum covering the vesical vessels and their intervening fascia (fig. 6). It will be evident that we have here, except for the fact that it is incomplete anteriorly, a peritoneal ligament for the genito-urinary organs better developed and more efficient as a visceral support than many of those described in the abdomen proper.

In the female the relative development of the connective tissue round the visceral branches of the internal iliac vessels is just as pronounced as in the male. The perivascular fascia is closely attached to the vaginal and uterine walls by the dense sheaths surrounding the vessels passing to these structures (fig. 7).

In the Fœtus.—The marked degree of development of the tissue between the visceral branches of the internal iliac vessels in the adult led me to

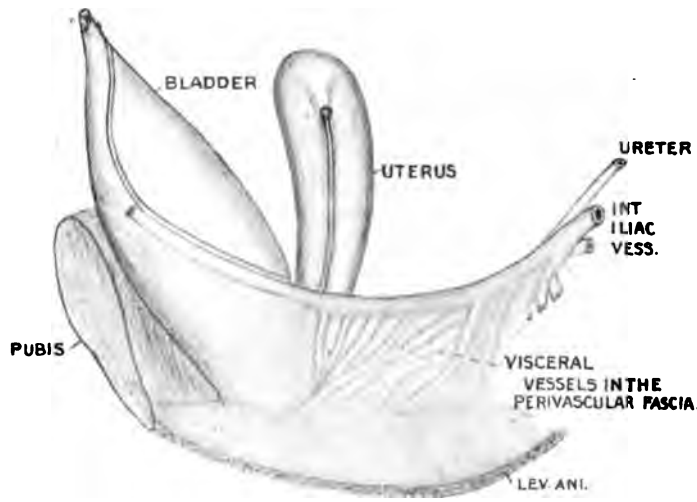


FIG. 8.—Pelvic viscera of female fœtus at full term. Enlarged.

examine these structures in the fœtus. It was found that even then one could readily recognise the unusual amount of intervascular tissue which is present in this region even at these early stages (fig. 8). It may be mentioned here that the compact nature of this tissue is best seen in subjects which have been injected with formalin.

Dissection.—In dissecting the pelvis the various visceral branches of the internal iliac vessels ought to be fully examined at this stage. One can then cut away these vessels at their attachment to the viscera and also at the point where some of them blend with the fascia on the pelvic surface of the levator ani. The latter fascia may now be exposed by removing the layer of loose areolar tissue which clothes its surface.

In this way a good view will be obtained of the white line passing from the back of the pubis to the ischial spine (fig. 9). This thickening is by no means always placed along the line of attachment of the levator ani fascia to the obturator fascia, as Paterson (5) and Thompson (8) have

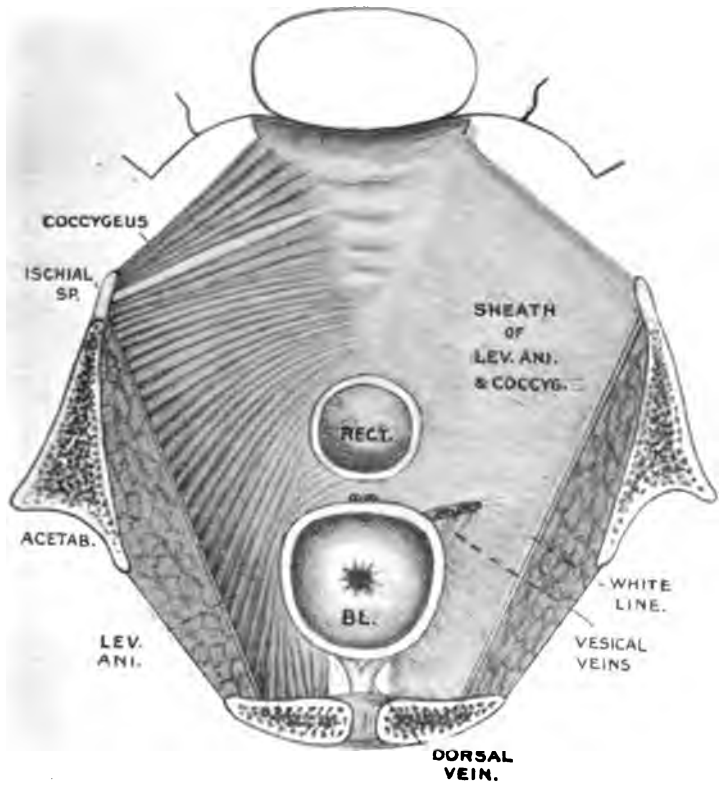


FIG. 9.—Male pelvis. The levator ani and coccygeus are exposed on the right side. On the left is shown their fascial sheath.

already pointed out. It may be entirely confined to the fascia of the levator ani, and often possesses a wavy course.

The disposition and attachments of the fascia on the pelvic surface of the levator ani and coccygeus are best appreciated by considering the origin and insertion of the muscle fibres. The levator ani arises mainly from the inner surface of the obturator fascia. In front of this its origin

extends on to the back of the pubis, and posteriorly on to the inner surface of the ischial spine (fig. 9). The attachments of the fascial sheath to these three structures exactly correspond with this (fig. 9). On tracing the fascia inwards, it again follows the course of the muscle fibres. Thus posteriorly it passes to the anterior aspect of the coccyx. In front of this it passes behind the rectum to the mesial raphe, and becomes continuous with the layer from the other side. Opposite the rectum it follows as usual the course of the muscle fibres downwards on the lateral wall of the anal canal, and blends with the connective tissue capsule of the latter. Hence the accepted description that the rectum carries down a sheath of the pelvic fascia with it, *i.e.* the so-called "rectal layer" of the visceral pelvic fascia. In front of the rectum the fascia again proceeds towards the middle line in relation to those fibres of the muscle which pass to the central point of the perineum. Still further forwards in the male pelvis the fascia follows the course of the muscle to the junction of the bladder and prostate. Note that at this point the large vesical and prostatic veins are imbedded in the fascia at its junction with the bladder and prostate (figs. 3, 5, and 9), the result being to produce a marked thickening and opacity of the fascia in this region. The latter is continuous through the sheaths of these veins with the connective tissue capsule covering the muscular coat of the bladder, there being thus no actual splitting of the *levator ani* fascia at this point. Here the fibres of the levator ani pass down on the lateral aspect of the prostate as the levator prostatæ, still covered by the fascial sheath which thus helps to form the lateral wall of the prostate capsule. Most anteriorly the fascia is continuous round the free margin of the levator ani with the fascial sheath on its under surface. This gives the rounded appearance to the pubo-prostatic ligaments (figs. 1 and 9). The latter structures are joined together across the middle line by a much thinner layer of connective tissue which is obviously a distinct structure, and is really derived from the sheaths of the dorsal vein of the penis and of a venous plexus in this region, the presence of which has been previously described by Richardson (6) and Paterson (5).

Posteriorly the fascia clothing the pelvic surface of the levator ani muscle is continuous with that over the coccygeus, and folds round the posterior border of the latter muscle to blend with the fascia on its under surface, *i.e.* the small sacro-sciatic ligament. This fascia has thus no direct association with that covering the pyriformis, though the two are united by a scanty and indefinite layer of connective tissue.

In the female the only point of difference in the arrangement of the levator ani fascia is the following,—opposite the vagina it is carried downwards with the muscle fibres to blend with the connective tissue capsule

on the lateral wall of that structure (figs. 7 and 10). Opposite the bladder the fascia blends with the capsule of that viscus through the medium of the sheaths of the vesical veins just as in the male (fig. 10).

From the foregoing description it will be recognised that, both in the

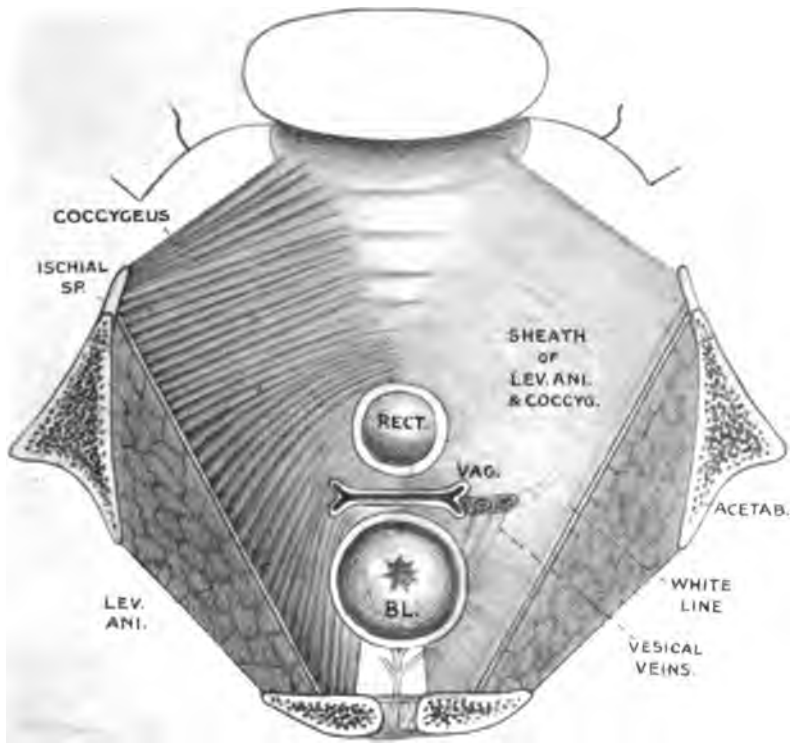


FIG. 10.—Female pelvis. The levator ani and coccygeus are exposed on the right side. On the left is shown their fascial sheath.

male and female, the fascia on the pelvic surface of the levator ani and coccygeus (the so-called visceral pelvic fascia) forms one *continuous fascial plane* in relation to these muscles, there being thus no actual splitting of this fascia into layers as is frequently described. Note again the relation of the large vesical veins to the fascia. They are imbedded in it as well as in the fascial capsule on the lateral aspect of the bladder. After a short

course backwards they leave the fascia to join the internal iliac vein along the line of attachment of the perivascular fascia. Thompson (8) has also been much impressed with the dense nature of the fascia surrounding the visceral branches of the internal iliac vessels. Thus he states: "At any rate we know that a fibrous sheath envelops the obliterated hypogastric artery, and the vessels supplying the bladder, uterus, vagina, and rectum and it may be that the supporting layers of the pelvic fascia are primarily derived from this by lateral extension on to the fascia covering the upper surface of the levator ani."

The results of my dissections show that the capsule of the prostate is formed by the sheaths of the veins which surround it, together with the fascial sheath of the levator prostatæ laterally and the sheath of the dorsal vein and pubo-prostatic ligaments anteriorly. The true connective tissue capsule of the gland is of course quite distinct from this, and is intimately blended with the gland substance.

I quite agree with Paterson (5) that the term "visceral" pelvic fascia ought to be abandoned, since it affords no clue to the morphology of this structure. It will be recognised from the foregoing description that this term includes the following:—

1. The fascia surrounding the obliterated hypogastric and the visceral branches of the internal iliac vessels.
2. The fascial sheaths of the prostatic plexus of veins and of the dorsal vein of the penis.
3. The fascia covering the pelvic surface of the levator ani and coccygei muscles.
4. The connective tissue capsules of the bladder, rectum, seminal vesicles and vas deferens, vagina and uterus.

The dissections in connection with this research were carried out in the Anatomy Department, University of Manchester, both in subjects preserved in the ordinary way and in those injected with formalin. I wish here to record my gratitude to Professor Young for the free use of material and for other facilities granted during the progress of the work. This research was begun under the terms of tenure of a Carnegie Fellowship, and I desire to express my indebtedness to the Executive Committee of the Carnegie Trust for a special grant of money to cover the cost of the illustrations.

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THE EVOLUTION OF MAN'S TEETH, FOUNDED UPON A STUDY OF THE DEVELOPMENT OF THE TEETH OF THE AUSTRALIAN ABORIGINAL.

By W. Ramsay Smith, D.Sc., M.B., C.M., F.R.S.E., *Permanent Head of the Department of Public Health of South Australia.*

At the present time there are two main theories regarding the phylogenetic origin of the heterodont dentition of man and mammals generally. Both theories agree in assuming that all varieties of mammalian teeth have been evolved from the primitive simple conical form of tooth. They differ, however, as to the mode of evolution.

The first is the fusion-of-cones or aggregation theory. It is stated thus by A. H. Thompson in Kirk's *American Text-Book of Operative Dentistry*, p. 17: "All tooth-forms are evolved by modification from a simple cone, which is the primitive typal form. The teeth of fishes and reptiles are but simple cones, and those of higher mammals are modifications of the single cone or combinations of two or more cones fused together. Thus in man the incisors are formed of a single cone, the truncated apex of which is compressed to form the wide cutting edge. The canine or cuspid is a single cone, the apex of which is compressed into a trihedral point or pointed pyramid. The bicuspids are composed of two cones fused together, the forms of the cones being quite distinct the entire length of the tooth, as in the upper bicuspids. The typal upper molar is formed by the addition of the third cone to the bicuspid form, as plainly noticed in the three roots and the primitive three cusps. The usual quadricuspid form is made by the addition of a cingule. The lower molar consists of four cones which may be plainly distinguished by an analysis of its elements. Each cone in the structure of a tooth is surmounted by a cusp or tubercle. Extra cusps above the number of primary cones are but cingules or undeveloped cusps. In the genesis of tooth-forms, therefore, the complex teeth, as the bicuspids and molars, are formed by the repetition and addition of cones and their accompanying cusps, both laterally and longitudinally, of the jaw."

It is said elsewhere that the evidence offered in support of this view is mainly embryological (*Quain's Anatomy*, vol. iii., pt. iv., p. 29).

According to this theory, which is advocated by Kükenthal and Röse,

it is supposed that a shortening of the jaw has given rise to a crowding together of two or more cones, followed by their fusion in order to form bicuspids, milk molars, and molars. Another supposition, according to this theory, is that such complex teeth might arise, not from antero-posterior fusion of cones, but from lateral fusion, and fused cones in this case belonging to different dentitions such as milk and permanent. Tims rejects the theory of lateral fusion, but allows the possibility of the antero-posterior fusion of two teeth of the same series. One case of Virchow's, in which three peg-like denticles took the place of a molar, has been regarded as a reversion, and is quoted as affording some evidence in favour of the theory of the origin of molars by fusion of cones.

Tomes criticises the theory adversely from the palæontological point of view. Osborn objects to it on the ground that the origin and addition of new cusps to long-settled perpetuated forms cannot be attributed to the appearance of a long-lost cone in order to form the new cusp, and that therefore cusps must have some other mode of origin than from cones.

The second theory is the cusp-addition theory advocated by Cope and Osborn chiefly on palæontological evidence. According to this view, cusps originate from the cingulum, which may be regarded as a sort of "mother of cusps." Tomes says: "Speaking generally, it may be said that new cusps are added to the number already existing by the cingulum becoming elevated into points; it is not very unusual to see subsidiary cusps obviously originating in this way upon human molars."

The "tritubercular" theory is a modification of the fusion-of-cones theory.

When writing on the subject of teeth some time ago, I said that some abnormal teeth that I had been describing supported the cusp-accretion theory, whilst another tooth seemed to yield strong support to the fusion-of-cones theory. Since that time I have studied a number of teeth of Australian aboriginals in various stages of their formation, and the conditions presented have proved very striking and very novel. For an animal with heterodont, diphyodont dentition, man is not very highly specialised in jaws and teeth; and since the Australian aboriginal is generally regarded as probably the nearest to primitive man, one naturally expects that some light may be thrown on the phylogenesis of mammalian teeth by a study of the ontogenesis of the teeth in individuals of the human race.

It will be well to begin by describing some of the teeth of one young subject, seen in the photograph, selected with the view of showing various stages in development.

No. 1 is a second bicuspid consisting of a saucer-like piece of dentine

surmounted by enamel and showing little if any constriction. No. 2 is an upper first bicuspid showing a slight ridge between two shallow pits. No. 3 is an upper molar consisting of a cup-shaped mass of dentine. The root-region shows a slight constriction. Internally the part of the dentinal cup adjacent to the enamel shows two shallow pits with a slight ridge between them. No 4 is another upper molar showing a more advanced stage. Here one constriction has cut off a portion that will become a root, from two other portions which are separated from each other by another constriction. Internally the dentine of the neck shows shallow pits and slight ridges. No. 5 is an upper right milk molar, and shows constrictions that have proceeded so far as to mark off the general form of a molar tooth. A long line marks the apposition of two edges which have not yet united sufficiently to make a complete division of the vascular and nerve elements of two of the roots. No. 6 is another



Under aspect of various developing teeth.

upper right milk molar, and shows a further stage in which the slits for the vascular and nerve elements are still shorter. No. 7 is a lower right milk molar, and may be regarded as the final stage in the evolution of an ordinary molar, and corresponds with the finished product.

I have examined a good many other specimens of teeth and jaws of infants and youths, and in all instances the same general features are exhibited.

The incisors and canines show some peculiarities similar to those mentioned in connection with the molars. One feature is the great size of the pulp cavity in the large hollow teeth up to a late stage in the development of the teeth. The result of this is that the jaws, especially the lower jaw, are excavated to such an extent that one wonders that fractures do not often occur through the very slim trabeculæ between the tooth-sockets. Probably, however, the hollow developing teeth are so firmly packed as to make the jaw in which they are embedded and the teeth themselves one resisting mass.

Another point to be noted is that portions of the jaw-bone immediately

underlying the teeth become moulded to form the root sockets at the same time as the constrictions appear in the primal tooth tube or cone.

One matter, when considered in connection with this subject of single-cone origin, possesses a good deal of interest. Edward John Eyre says, regarding Australian aboriginals in vol. ii. p. 206 of his Journal, 1845: "The lips are rather thick, and the teeth generally very perfect and beautiful, though the dental arrangement is sometimes singular, as no difference exists in many cases between the incisor and canine teeth." Mr J. D. Woods, in *The Native Tribes of South Australia*, 1879, p. xxxvii., says: "The teeth are beautifully regular, but the incisors are not sharp, like those of the European, but flat, and not unlike molars." To those who know a little about the teeth of aboriginals these statements may appear ridiculous; to those who have paid close attention to the subject they appeal as being accurate. When one examines the worn-down teeth very commonly met with in blacks from some localities, one notices the flattened incisors, devoid of enamel tips, very like bicuspids and molars, and showing the same peculiarities. They remind one of the "gouty" teeth of the white subject. The similarity of incisors to canines is even better marked, and is oftener seen.

It appears that when teeth begin to retrograde they revert in the individual to something corresponding with what may be supposed to be the primitive conical form worn down to form a peg. At any rate they show a strong tendency to become like one another. I am sure it would puzzle many dentists and anatomists to classify some Australian teeth as incisors, canines, or bicuspids. This change appears to be closely associated with the monotony of diet that exists in some localities.

The subject of change in form of the teeth naturally leads one to refer to Tomes' criticism of Cope's theory, in which Tomes assumes the unalterableness of dentine once it is formed (*A Manual of Dental Anatomy*, 1904, p. 368).

No one who has had an opportunity of examining many aboriginal teeth of the sort I have referred to can conclude that dentine, when once formed, is unalterable. The evidence is that it is alterable at all stages. This fact is further shown in what is called "dislocation" of the teeth. In this condition the lingual root of the molar retains its position in the alveolus, while the buccal roots change, in a very considerable degree, the angle they make with the lingual root; and this occurs by moulding without any absorption of the dentine of any of the roots. Accretion or hypertrophy of the dentine, if it occurred, would obviously decrease the angle.

This mutability or "malleability" is of great importance in connection with this question of evolution of heterodont forms. I have observed that

the enamel cap in the unworn teeth of aboriginals forms a covering of very uniform thickness over the crown of dentine which, when denuded of this covering, closely resembles the external enamel surface itself in outline and configuration. The dentine, at the limit where it is in contact with the enamel, would appear to be "sensitive," "reacting," or "responsive" to pressure, and to meet requirements by becoming cuspid. The dentine is really the plastic or malleable material in the formation of roots and cusps alike, the enamel being merely a layer of more or less uniform thickness closely investing the crown with its tubercles or cusps like a non-sensitive epithelial or epidermic coating.

It has to be noted in connection with the appearance of cusps at an early stage of development of teeth that the teeth of the Anoplotherium, one of the most primitive of all mammals, show a gradual transition from incisors to molars with a corresponding complexity of cusps; so that cuspidation appears to be a very early phenomenon in the mammalian class. One infers that if this condition was not inherited by the mammals it was very early and very easily acquired by them. Further, it does not appear that the jaws of the Anoplotherium were so much "foreshortened" as would compel a "cuspidation" of the teeth by compulsory antero-posterior fusion of primitive Sauropsidan or Ichthyopsidan cones.

One important fact to be learned from the specimens I have examined is that the compound form of the tooth, due to the formation of roots by plication or constriction, does not appear until direct pressure has been exerted on the tooth. Teeth that have not erupted show no such formation. This has an important bearing on the subject of the simplicity of premolars as compared with milk molars and permanent molars. In some other races as well as Australian aboriginals, as is seen well marked in some skulls I have described from New Caledonia, the milk molars are extremely large and molar-like, and are a good deal worn on the grinding surface. They had for a time been doing all the grinding and crushing work of molars in such a position at the part of the jaw nearest to the fulcrum as allowed them to act with the greatest effect. As the jaw extended backwards, the permanent molars appeared and took up, in succession and in addition, the work previously done by the milk molars, the roots developing as the pressure began to tell upon these teeth. When the bicuspids were developed, the same forces were not at work to form or to mould their roots as in the case of their predecessors, since the function of grinding and crushing had been assumed by the molars. The succession in time of molars and bicuspids bears this out in a remarkable manner. At the seventh year there are two milk molars and a permanent molar for grinding or crushing purposes, and this condition continues till the tenth

year, when the first molar gives place to the first biscuspid. This leaves only two grinders (viz., the second milk molar and the first permanent molar) till about the thirteenth year, when the second permanent molar may have come and the second milk molar may have gone. Two grinding teeth at any one time would seem to be sufficient functionally, at least in the higher races.

This subject of root formation or moulding has to be co-ordinated with the physical facts regarding the strength of a tube and the resistance to pressure of the parts underneath and surrounding it. A hollow tube of a certain diameter and thickness is the strongest structure possible with a given amount of material at disposal. Further, a constricted tube gives additional strength, while the roots distribute the pressure to the adjacent bony parts of the jaws. The upper jaw, being softer and more spongy, has usually a larger number of roots implanted in it.

What light do these specimens and observations cast on the evolution of man's teeth? They show that cuspidate teeth, like canines and incisors, are developed from a simple tube of dentine tipped or topped by enamel. They show also that this development takes place by constriction. What is the explanation of the tubular form which the specimens present? Is this tube the original cone from which such teeth are supposed to be developed? If not, does it represent a stage in evolution later than the supposed stage of fusion of several cones? Surely it were a work of supererogation for two, three, or four primitive cones, either in the individual or the race, to go through a stage of fusion, then by absorption of their adjacent septa to become hollowed out into a single simple cylinder or cone or tube such as is presented by these specimens, only to become finally reconstricted to form milk molars, bicuspids, or molars as the case may be. It seems to me that there neither is nor has been any such fusion or absorption, but that the complicated milk molars, premolars, and molars are formed by plication or constriction of an original primitive single simple cone or tube according to the method demonstrated by these specimens.

It is not too much to claim that the whole theory of the origin of "heterodont" teeth from fused primitive cones, as well as the theory of aggregation of cusps in so far as it involves the origin of roots, will have to be reconsidered in the light of these and similar specimens from Australian aboriginal subjects. Further, some exceptional abnormalities of fusion of teeth may be best explained in accordance with this mode of development from one primal tube.

SEVENTEENTH REPORT ON RECENT TERATOLOGICAL LITERATURE.

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[The author of this report will feel greatly obliged if writers on teratological subjects will supply him with reprints of their papers for use in the preparation of future reports.]

I. EXPERIMENTAL.

JENKINSON (i.) has noted the effect of solutions of certain salts, cane sugar, dextrose and urea upon the development of the frog's egg. The different solutions do not produce the same effects. They can be classified into (*a*) solutions which kill the egg at an early stage, (*b*) solutions which kill the egg at a later stage, (*c*) solutions in which development proceeds but in a distorted manner, (*d*) solutions in which development is retarded, (*e*) solutions in which development is normal in form and rate. He believes it impossible to attribute these diverse effects to osmotic pressure and to that alone. He finds that the yolk cells are first affected. Among the unusual results of his experiments he finds that the notochord may be formed from the whole thickness of the archenteric roof, that the lumen of the brain and its outgrowths may be greatly reduced, that the lens may be absent though the optic cup be present, that accessory "enteric" and "neural" notochords may be formed.

II. GENERAL.

DE SANCTIS (ii.) contributes a work on *infantilism*. He describes eight cases of the condition and two cases simulating it. He attributes the condition to altered internal secretions, and gives the following classification:—

- Complete.
  - Dystrophic.
    - Hereditary Syphilitic.
    - Anangioplastic.
    - Chlorotic.
    - Tubercular.
    - Alcoholic.
    - Mitral.
    - Hereditary Pellagrous.
  - Myxœdematous.
  - Mongoloid.
  - Cretinoid.
  - Dysgenital.
  - Mixed.
- Incomplete.
  - Hemi-infantilism of Brissaud (?).
  - Partial Infantilism
    - of the sexual organs.
    - ,, intelligence.
    - ,, voice.
    - ,, stature.
    - ,, piliferous system.
    - ,, cardio-vascular system.
    - of language.

TILLOY (iii.) gives an account of autopsies on two infants of the mongoloid type. He found the thymus and thyroid both healthy. The cells of the cerebral cortex showed no decrease in number. There was a slight increase of neuroglial tissue. SALMON (iv.), in a paper on *phocomelus*, contends that the condition is a form of achondroplasia. The bones are the parts most affected; the muscles and other soft tissues are never so proportionately reduced as are the osseous parts. The bony segments of the limbs are rarely entirely absent, and though reduced are more or less homologous to the corresponding bones of normal anatomy. They are generally curved, twisted and deformed; in some cases they fail to recall in any respect normal bones. SOLOMON (v.) describes an *achondroplasic fœtus*, and remarks on the thickness of the skin, the localisation of the malformations to the limbs, and particularly to their superior segments, the shortness of the limbs, and the characteristic forms of the bones. He emphasises the close relation between achondroplasia and phocomelia. RANKIN and MACKAY (vi.) contribute a paper on *achondroplasia*, and describe in detail one case—a boy of nine years. Signs of rickets were also present. The photographs accompanying the paper particularly illustrate the size and configuration of the head and the marked discrepancy between the body and the limbs. LOVETT and NICHOLS (vii.) discuss *osteogenesis imperfecta*, and describe a case. Both femora and tibiæ were fractured at birth; there were in all ten partial or complete fractures, no one of them occurring after the age of five months. The patient lived to the age of ten months. An autopsy was performed, and a full account of the abnormal bone formation is given. SALMON (viii.) describes the histological structure and the development of the *osseous tissue in ectromelian monsters*. In the pre-cartilaginous stage the tissue may be seen to evolve partly or entirely into fibrous tissue instead of into cartilage. The cartilage before the appearance of centres of ossification breaks into several pieces, due to an invasion by fibrous tissue. The points of chondrification appear irregularly and fuse irregularly with each other. KERMAUNER (ix.) describes an unusual case of *spina bifida*. Properly speaking there is no neck, its place being taken by a large collection of fat. The spina bifida is confined to the dorsal region. The condition is attributed to a hydramnios. Its limitation to the upper half of the body is explained by assuming the embryo fixed for a time in an abnormal position through amniotic adhesions. RABAUD (x.) discusses the causes of *spina bifida*. He contends that the forms of spina bifida should be separated into two distinct groups. As an example of one group he takes myelomeningocele, which he attributes to fœtal meningitis; the other group is represented by a myelocystocele, which springs from an embryological process of which the initial stages are characterised by the formation of a medullary area very extended in width. RABAUD (xi.) deals in a special publication with the *pathogeny of pseudencephaly and anencephaly*. He concludes that the two conditions represent different degrees of the same congenital malady — that this malady is a meningitis, at first cerebral but later spreading to the spinal meninges. The fœtal meningitis does not differ from that of the adult, except that owing to the parasitic nature of the fœtus a stronger resistance to death is offered. The inflammation extends to the underlying nervous tissues, in which abundant hæmorrhages occur. Little by little the cerebral tissue disappears, and in its place is found a vascular tumour. Variations may occur in this process, *e.g.* the intra-cerebral hæmorrhages and the sero-sanguineous exudation may destroy all the nervous tissue before the formation of the vascular tumour. Sometimes all that remains in the neural canal of the spinal cord are the posterior nerve roots. Later the membranous cranium is destroyed while the cartilaginous is spared. Much of

the final state depends on whether the meningitis supervenes early or late. The origin of the meningitis is in no way concerned with anomalies of the placenta or amnion. If these latter occur, they are to be regarded as the result and not the cause of the inflammation. The infective agent is probably very variable and microbic. SPILLER (xii.), a case of *syringomyelia*, extending from the sacral region of the spinal cord through the medulla oblongata, right side of the pons and right cerebral peduncle to the upper part of the right internal capsule. BOLK (xiii.) describes a case of *doubling of the spinal cord in didelphis cancrivora*. At the level of the 6th cervical vertebra the cord begins to widen; at the level of the cervico-thoracic junction there are two cords side by side joined by a broad isthmus; at a lower level the original cord separates and diminishes; the secondary cord remains and enlarges. KAESTNER (xiv. and xv.) has two important papers on *omphalocephaly in bird embryoes*. In addition to a general discussion of the subject he gives an account of three cases studied by Plattenmodellen. He finds that omphalocephaly is a definite condition which develops relatively late, when there are at least fourteen segments. The heart is normal in its situation and size; it is the head which, turning ventralwards behind the heart, produces the deformity. The foregut which is present before the head is dislocated disappears, but another foregut is formed at a later stage. The parts, although so abnormally situated, continue to grow and develop. Death occurs from rupture of the ascending aorta through pressure and tension. DIETRICH (xvi.) describes a case of *paracephalus amelus macrocardius heteromorphous* presenting certain unique characters. The primary defect is considered to be the non-development of a venous system. Perhaps, however, this in its turn is due to failure of the liver anlage, and so of the inferior vena cava. SCHWALBE (xvii.) describes a case of *epigastrius parasiticus* in a child eleven weeks old. The parasite was large, consisting of the two lower extremities, male genitalia, lumbar portion of trunk, and rudiments of the upper extremities. It was attached between the xiphoid cartilage and the umbilicus. It was removed by operation, but the child died two hours afterwards. The parasite received its blood supply from the right internal mammary and right epigastric arteries of the host. The abdominal organs of the parasite lay in the peritoneal cavity of the host, but there was no union between the viscera. One of the most interesting features was the entire absence in the parasite of striped muscle, motor nerves and central nervous system. Sensory nerves were present. They could be demonstrated in the skin, and pain felt in the knee of the parasite was the occasion of the operation. The place of the striped muscle was taken by fat. KERMAUNER (xviii.) contributes a paper on *malformations associated with imperfect closure of the body cavity*. He argues that the cause of the latter condition, to which the deformities are in part secondary, is a hydramnios, possibly due to some chemical substance in the blood of the pregnant woman. The hydramnios is associated with an adhesiveness of the amnion. The amnio-chorionic space, normally filled with a gelatinous substance, is obliterated. Although the amniotic space enlarges, the body stalk remains of normal length. The body stalk being relatively short, the amniotic cavity large, and the specific gravity of the fœtus slightly greater than that of the amniotic fluid, considerable movement is permitted, with disturbance particularly in the region of the umbilicus. Incidentally he describes a case in which the cæcum possessed two vermiform appendices. SIPPEL (xix.) reports a case in which a man married twice. His first wife bore him twelve children, all free from malformation. On her decease he married her sister, who bore him seven children—three girls and four boys; all four boys were congenitally afflicted. He holds that the obscure origin of four

marked congenital malformations must have lain in the mother, the second wife. The affected children being male, he thence argues that their sex is due to their mother. Dyson (xx.) describes a case of *transposition of the viscera* recognised during life. The heart, liver, and spleen were affected. Schwalbe (xxi.) enters into a general discussion of the theories of *tumour formation* in the light of teratology. He instances such tumours as epignathus, sacral teratoma, dermoid cyst, which he attributes to *entwicklungstörung*. Many such tumours are not present at birth, but develop in the first year; many give rise to metastasis; in these respects he sees an analogy between them and other tumours which may, so he argues, be similarly due to *entwicklungstörung*. He anticipates great help from the experimental formation of tumours in the embryos of cold-blooded animals. Doyen (xxii.) finds that the *intra-peritoneal inoculation of micrococcus neoformans* is able to produce in white rats lesions identical with the metastatic enchondromata of the lungs of dogs. Shattock (xxiii.), the colour of the hair in *ovarian dermoids*. Holding (xxiv.) describes briefly and illustrates certain cases of teratology in animals, cases of supernumerary limbs, a foal with complete absence of the fore-limbs, a dog with a large epigastrius parasiticus, a cow with opodymia. Perhaps the most rare case is that of a cow, from the angles of whose mandible depended a tumour containing the lower jaw, teeth, and tongue of a calf.

III. Duplicity.

Schwalbe (xxv.), a *systematic classification of double monsters*, with special attention to those which are symmetrical, and with illustrations drawn from cephalothoracopagy (Janus).

Lesbre and Forgeot (xxvi.) write on *hypsiloid and xioid monsters*. They give the following classifications:—

Hypsiloid.

Psodyme.	Bifurcation at the level of the loins.
Xiphodyme.	,, ,, lower border of the chest.
Thoracodyme.	,, near the middle of the chest.
Sternodyme.	,, at the root of the neck, four thoracic limbs.
Derodyme.	,, ,, ,, ,, ,, two ,, ,,
Atlodyme.	Two free heads, the vertebral column bifurcating at the level of the atlas.
Iniodyme.	Two heads united behind, the occipital region, neck and body being single.
Opodyme.	A single head with two faces.
Rhinodyme.	A single head—doubling only in the nasal region.

Xioid.

A.—Forms derived from ischiopagy by ventral convergence—

1. Ischio-xiphiopagy.
2. Ischio-thoracopagy.
3. Ischio-sternopagy.
4. Ischio-stomopagy, foreseen but not yet observed.

B.—Dyme-delph forms or rachipagy—

1. Thoracodyme-ileadelphus.
2. Sternodyme-ileadelphus.
3. Derodyme-ileadelphus.
4. Atlodyme-ileadelphus.
5. Iniodyme-ileadelphus.
6. Opodyme-ileadelphus.
7. Rhinodyme-ileadelphus.

Ruban-Elisselewa (xxvii.), a case of *janiceps, cranio-rhachischisis and anencephalus.* The vertebral column is divided down to the second lumbar vertebra. The condition is attributed to a partial division of the blastula.

Ragnotti (xxviii.) describes three cases of *double monstrosity* in *Rana europœa.* They support the view of Hertwig as modified by Kopsch that such duplicity results from two gastrular invaginations, which approach nearer and nearer to each other and ultimately fuse. Reese (xxix.) describes and figures two alligator embryos on a single yolk. There are fifteen pairs of mesoblastic somites, and the neural canal is practically enclosed. While entirely distinct, they lie so close together that their vascular areas are flattened against each other. They are of approximately the same age or state of development.

Van den Broek (xxx.), a *double monster of Talpa europœa.* There are two bodies and four thoracic limbs, but the facial portion of the skull is single. There are only two eyes and two choanæ. The central nervous systems fuse at the rhombencephalon, but from microscopical examination the central nervous system is only single in the region of the lamina terminalis. Although there are two prosencephala, there are only two optic tracts. There are, however, two hypophyses, both the neural and buccal components being present. There are three auditory vesicles. The mouth, tongue, pharynx, œsophagus, stomach, liver, pancreas, larynx, trachea, lungs, heart are those of a single individual. The stomach has a single anterior mesogastrium, but two posterior mesogastria. The small intestine is single as far as the omphaloenteric duct; here it splits into three portions, one going to each embryo; the middle one, forming the small omphaloenteric duct, seems to continue the line of the small intestine. Gauthier (xxxi.), a case of *uterus didelphus.* Each uterus possessed a distinct vagina and complete set of tubes and ovaries. Chill (xxxii.), a case of *fissura abdominis with duplication of the external genitalia,* which were separated from one another by a clearly defined central space. There were also two anal orifices. The child was of the female sex. Ognew (xxxiii.), a case of *hermaphroditism* in *Rana temporaria.* A summary of the other cases in the literature is given.

IV. Head and Neck.

Audebert (xxxiv.) gives an account illustrated by two excellent photographs of *multiple malformations of the face and cranium by an amniotic band.* The umbilical cord is wound three times round the band, which latter has acquired an attachment over the frontal region of the cranium. Grynfelt (xxxv.) describes a case of *fronto-nasal encephalocele,* the tumour lying above the nasal bones. The cerebral hemispheres were considerably atrophied and their ventricular cavities dilated.

Rabaud (xxxvi.) describes a somewhat circular depression of the *cerebral cortex of the parietal lobe.* It was found on both sides of the cerebrum, the depression on

the right hemisphere being the better marked. Its cause is unknown; it is not the result of a hæmorrhage. SAUERBECK (xxxvii.), a case of *malformation of the brain in Hatteria punctata* (*sphenodon punctatus*). An open neuroporus is the primary defect. Through it has passed a large portion of the brain in a manner comparable to a prolapsus uteri. The cranium was cleft dorsally and small, the greater part of the brain lying outside it. The orbits are small, the eyes malformed —the retina and lens being absent—the ocular muscles irregularly developed. The anlage of the pineal eye was double, divided by the deformity; there was again no sign of a lens. The mechanical and amniotic theories for explaining the anomalies are discussed. VON HIPPEL (xxxviii.) describes certain anomalies of the *eye and orbit*: (1) a *congenital teratoma of the orbit*; it was composed of tissues representing all three layers of the embryo. He discusses congenital teratomata of the orbit generally, and compares them with teratomata of the mouth and ovary; (2) a *case of bilateral congenital anophthalmus with encephalocele of the orbit.* The absence in the same subject of both thumbs suggests an amniotic explanation. Fœtal tuberculosis of the bulb is also suggested, suppurative inflammation excluded; (3) *congenital cryptophthalmus associated with webbed fingers* and other congenital anomalies, attributed to abnormal amniotic influence; (4) *epibulbar dermoid with a rudimentary bulb and coloboma of the upper lid.* In this case remains of amniotic structures were observable on the nose and cheek. VON SZILY (xxxix.) shows how the amnion may produce congenital deformities of the eye. He figures the lens anlage during invagination with an amniotic fold enclosed. THORPE (xl.), a case of *congenital iridodialysis with heterochromia.* There is a history of a similar condition in the mother and grandmother. HENSLOWE WELLINGTON and SOUTER (xli.), cases of *heterochromia iridis.* BRAILEY (xlii.) contributes a paper on *congenital distichiasis*, and gives a clinical description of one case in which the chief point of interest was the complete absence of the Meibomian glands, their place being taken by hair follicles. NETTLESHIP and OGILVIE (xliii.) give an account of a family in which twenty persons in four generations had *congenital cataract.* All the cases occurred in one branch of the family tree. NORTHCOTE (xliv.) describes a case of *congenital occlusion* of both external auditory meatuses by a membranous septum situated ¼-inch from the surface. The sense of hearing is not in abeyance. LEUZI and PELLEGRINI (xlv.) describe fourteen cases of *congenital cervical cyst*; eight were in the middle line, six were lateral. They believe that any congenital cyst of the neck is either derived from the thyroid gland or is a branchial cyst proper. The median cysts all contain thyroid tissue, and in five out of the eight cases they are pathological developments of aberrant thyroid glands. The lateral cysts have a branchial origin. CALDAGUES (xlvi.), a case of *branchial epithelioma.*

V. THORAX.

BORST (xlvii.) describes a *heart with three auricles* due to the division of the left auricle into an upper and lower part by a septum pierced by a round hole. The septum is regarded as a persistent septum primum and the aperture in it as the persistent ostium primum of Born.

AMEUILLE (xlviii.) describes the case of a girl aged 16 in the interventricular septum of whose heart existed a *small oval orifice* 3 mm. by 1 mm. It is situated, as seen from the left ventricle, just below the right and posterior semilunar cusps of the aortic valve. A probe passed through it enters not the right ventricle, but the right auricle, due to a fusion between the left cusp of the tricuspid valve and the

interventricular septum. It is regarded as being more probably the result of inflammation than due to a malformation.

BLUNTSCHLI (xlix.) describes an *abnormal vena azygos major* which lies between mesial and lateral segments of the upper lobe of the right lung. The case is not isolated, and is attributable to the fact that the subclavian vein being originally a branch of the posterior cardinal, any delay in its later connection with the anterior cardinal will prevent the posterior cardinal moving inwards and so cause it to lie lateral to the root of the lung.

VI. ABDOMEN.

GERHARTZ (l.) describes two cases of *accessory testicle* in *Rana fusca*. In one of the cases there were also accessory livers. The accessory testicle is attributed to division of the anlage, the accessory livers to abnormal vascular formations. CANTLEY (li.) has a paper on *congenital hypertrophic pyloric stenosis*. In hypertrophic stenosis the pylorus forms a hard, elongated cylindrical tumour $\frac{3}{4}$-inch to 1 inch in length, and about $1\frac{1}{2}$ inches in circumference—a solid tumour about the size of the last joint of the female little finger. The enlargement is due to a great increase in the circular muscle fibres, a true hyperplasia, a simple redundancy of fœtal growth, possibly of an atavistic origin. GILLMORE (lii.), a case in which the *uterus and fallopian tubes were absent*; the vagina was a pouch under 1 inch in length. There was a double inguinal hernia with an ovary in each sac. There was a regular monthly molimen with profuse epistaxis. MOREL (liii.) describes a case of *Meckel's diverticulum*. There were glands of the Lieberkuhn type in the mucous membrane of the diverticulum, but only in its proximal portion. DUDGEON (liv.), a case of *malignant teratoma of the ovary* occurring in a child 3 years 11 months of age. Examined microscopically the tumour showed spaces lined by cubical and in some cases columnar epithelium. In the latter case there was a resemblance to intestinal mucous membrane, a resemblance which was more marked where some of the spaces were surrounded by patches of lymphoid tissue. Embryonic cartilage cells, squamous epithelium, unstriped muscular fibres were also present, the latter being particularly abundant.

VII. EXTREMITIES.

SCHWALBE (lv.) contributes a paper on *malformations of the extremities*—split hand, split foot, syndactyly, adactyly and polydactyly. The paper is illustrated by specimens, which put beyond doubt the fact that in some cases at least, if not in all, the conditions result from amniotic bands. That they may be due to other causes is possible, but unsupported by any known facts. The appearance of one or other in members of a family is not due to the condition being hereditary, but to the inheritance of the amniotic anomaly which produces the condition. Polydactyly in the light of experiment is to be explained as hyper-regeneration and not as atavism. KLAUSSNER (lvi.) has published a work on the *malformations of man's limbs*. He deals among other matters with gigantism, absent radius, syndactyly, polydactyly, brachydactyly, electrodactyly. DARTIGUES and CARAVEN (lvii.), a *case of polydactyly of a hand and two feet*. The supernumerary digit of the hand has three phalanges; it is situated on the ulnar side. The supernumerary digit of the right foot is larger than the fifth or even the second toe. It is on the outer border of the foot. That of the left foot is smaller than the fifth toe, and disposed as a hammer on its dorsal aspect. FICAI (lviii.) describes a case of *congenital amputation of fingers and toes*

combined with syndactyly. The anomalies are symmetrical: in the case of the feet the fifth toe is absent; in the hands there has been an amputation of two fingers, with syndactyly of the remaining two. SOULIGOUX and DAVID (lix.), a case of *macrodactyly*, the index of the right hand, especially its last two phalanges, being affected. FÉRÉ (lx.) describes a case of *digitus minimus valgus* combined with a rotation of the little finger on its axis and a flexion at its distal interphalangeal joint. KLIPPL and RABAUD (lxi.) describe a case of *right thoracic hemimelia*, and enter into a discussion as to the nature and origin of the process. They conclude that the hypothesis of a congenital amputation with secondary budding from the amputated limb is untenable. The condition is due to arrested development from a cause which remains unknown, but which is neither amniotic compression nor lesion of the nerve centres. CUTORE (lxii.) describes a case of *perobrachius achirus*, a variety of hemimelia. The interesting feature is that although there are no osseous structures beyond the shortened and malformed radius and ulna, the soft parts have been able to produce a form of hand, possessing five digits, and closely resembling in morphological characteristics the hand of normal anatomy. RENNIE (lxiii.) describes two cases of *accessory fins* in *Raia batis*. The abnormality, possibly the outcrop of a migrant germ cell, reproduces a condition found in different elasmobranchs.

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JOURNAL OF ANATOMY AND PHYSIOLOGY

THE COMPARATIVE ANATOMY, GROSS AND MINUTE, OF THE THYROID AND PARATHYROID GLANDS IN MAMMALS AND BIRDS.

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(From the Physiological Laboratory, Guy's Hospital, and the Pathological Laboratory, Charing Cross Hospital.)

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I.—INTRODUCTION AND SUMMARY OF PREVIOUS INVESTIGATIONS.

ALTHOUGH a considerable amount of work has been done on the comparative anatomy of the parathyroids, most investigations have, not unnaturally, been restricted to the more easily obtained bodies of domestic animals. Sandström (16), the first to describe the parathyroids, dissected the dog, cat, rabbit, horse and ox, and in each concluded that there was one parathyroid to each thyroid lobe. Baber (1) examined many thyroids and described in those of the dog, cat, and pigeon "undeveloped areas" of

thyroid tissue, and his account of these appears to tally with that of Sandström's parathyroids, with this distinction, that whereas the latter described the parathyroids as isolated by connective tissue from the thyroid beneath, Baber states that his areas might be not distinctly separated from the rest of the gland. Horsley (9) and Rogowitsch (15) confirmed the occurrence of embryonic tissue in association with the thyroid.

Kohn's (11) research is of special value in that it led to the conclusion that there were normally two parathyroids on each side in the dog, cat, rabbit and guinea-pig, one on the lateral and one on the tracheal surface of each thyroid lobe. This discovery derived its importance from the fact that hitherto operators had not taken into consideration the possible existence of more than one gland on each side.

During the past ten years the subject has been taken up by Gley (7), Nicolas (13), Cristiani (3), Vassale and Generali (19), Moussu (12), Verdun (20), Simon (18), Groschuff (8), Ver Eecke (21), Easterbrook (4), Prenant (14), Capobianco and Mazziotti (2), Torretta (18*a*), Alquier (1*a*), Berkeley (2*a*), Rogers and Ferguson (14*a*), Jeandelize (10) and others, who, in addition to the animals already mentioned, examined the monkey, fox, goat, pig, horse, seal, bat, rat, mouse, and some birds. They agree that the parathyroids number four, except in some species where only two are present. So constant are these numbers stated to be that Groschuff goes so far as to suggest a classification of mammals into two divisions according to whether the parathyroids are two or four. Recently Vincent and Jolly (22) examined the glands in certain animals in the course of experiments on the effects of parathyroidectomy. In dogs, cats, monkeys, rabbits, prairie-wolves and badgers they recognise two parathyroids on each side and in the rat only one. To a study of the glands in the guinea-pig they devoted considerable time, with the result that they found the number and position of the parathyroids to be extremely variable, as many as six occurring in one animal.

As regards the position of the parathyroids they have generally been described as lying, the external on the lateral surface of the thyroid, the internal on the tracheal surface, often depressed in the main gland but always separated from it by connective tissue. They vary in position between limits. In animals with only two parathyroids it is the internal one that is stated to be absent, while the external parathyroid in the rabbit was found by Gley (7) to be commonly 5 mm. posterior to the thyroid applied against the carotid artery; but he mentions that in this animal parathyroids may be wholly absent on one side of the neck. In the goat the external parathyroid is stated to lie in contact with the deep surface of the submaxillary gland (12). Moussu (12) has noted the occurrence of

supplementary parathyroid glands in the dog, though Jeandelize (10) doubts their existence. Shaper (17) states that in the sheep he has very frequently found nodules with a parathyroid structure near the bifurcation of the common carotid, and others, two, three or more, along the course of the carotid. Jeandelize (10) has confirmed this statement.

A study of the literature on the subject forces one to the conclusion that few if any of the authorities quoted have protected themselves from the criticism that they allowed their unaided eye to attempt what only the microscope could effect. It is admitted that the parathyroids are exceedingly difficult to find, that it is possible to mistake them for lymphatic or accessory thyroid glands, and that they may be buried deeply in the thyroid lobes. Yet sufficient attention has not been paid to these facts. If parathyroids often possess no naked-eye characteristic whereby they can be identified, no attempt to enumerate them will be successful unless every glandular body found within wide limits of the thyroid is subjected to microscopic examination. Except, perhaps, for Vincent and Jolly's work (22) on the parathyroids of the guinea-pig, there has been, as far as I can find, no such detailed quest undertaken. Occasionally, though rarely, accessory parathyroids have been described, but since Kohn's work in 1895 four parathyroids have been looked on as the greatest number present.

In the present research 77 animals, comprising 42 mammals and 35 birds, have been examined. The procedure adopted was as follows:—The neck of each animal was carefully dissected and every glandular body, no matter how small, and including all on the surface of the thyroid, was subjected to microscopical examination. The thyroid itself, if small, was examined by serial sections, but if large was cut into thin slices, the surfaces of each of which were scrutinised with a lens and all suspicious-looking pieces retained for microscopical examination. In brief, the guiding principle followed was to regard every gland as a possible parathyroid, and none has been identified except by its microscopical features.

This detailed search has led to conclusions at variance with those already quoted, and from the following pages it will be found that the parathyroids vary widely in number in different species and even in different members of the same species. An instance of this is afforded by three specimens of the Green Monkey (*C. callitrichus*) in whom the parathyroids numbered 1, 1 and 8 respectively. Further, the existence of parathyroid tissue in the thyroid, not isolated by connective tissue, has been found to be of much commoner occurrence than was anticipated.

It is not proposed in this paper to do more than record the details relating to each animal or bird examined. The explanation of the facts

and the conclusions to be drawn from them will be reserved for consideration in a subsequent paper (6), when they can be taken in conjunction with facts already established concerning the human parathyroid glands (5). For the present it will be sufficient to draw attention to the broad conclusion that even in the same species the parathyroids are subject to variations in number and in position, and it is probable that in no mammal at any rate is the number of parathyroids constant. Further, parathyroid tissue is commonly present in the thyroid, and intermediate types are readily found both in the thyroid and in accessory glands, with the result that the identity of some bodies has often presented difficulty. Under these circumstances it might have appeared undesirable to retain the two expressions thyroid and parathyroid; but since the histological distinction between the two is widely recognised and is a convenient one, it was found advantageous to employ both in the following descriptions. This usage is not to be taken as an assent to the proposition that there is a functional difference between the thyroid and the so-called parathyroid glands. In the following pages a gland which presented the gross anatomical features of a thyroid will be spoken of as a thyroid even though its structure is wholly or in part parathyroidal, while those smaller accessory glands which were partly vesicular and partly non-vesicular will be regarded as thyroidal or parathyroidal according to which type of structure preponderated.

Appended is a classified list of the mammals and birds that have been examined, and of whose thyroids and parathyroids a description is given.

I. MAMMALIA.

Order PRIMATES.

CERCOPITHECIDÆ.

Cynopithecus niger (Black Ape).
Cercopithecus callitrichus (Green Monkey).
" " (2nd specimen).
" " (3rd specimen).
Cercopithecus Campbelli (Campbell's Monkey).
Cercocebus collaris (White-collared Mangabey).
Macacus nemestrinus (Pig-tailed Monkey).

Order CHIROPTERA.

PTEROPIDÆ.

Cynonycteris collaris (Collared Fruit-bat).

Order CARNIVORA.

FELIDÆ.

Felis serval (Serval).
Cryptoprocta ferox (Fossa).

VIVERRIDÆ.

Viverra civetta (African Civet-cat).
V. tangalunga (Sumatran Civet).
Gennetta felina (Feline Gennett).
Nandinia binotata (Two-spotted Paradoxure).
" " (2nd specimen).
" " (3rd specimen).
Paradoxurus hermaphrodita (Malayan Paradoxure).
Herpestes auropunctatus (Spotted Ichneumon).
" " (2nd specimen).
Suricata tetradactyla (Suricate).

HYÆNIDÆ.

Hyæna crocuta (Spotted Hyæna).

CANIDÆ.

Canis lateralis (Side-striped Jackal).

MUSTELIDÆ.

Mustela vulgaris (Weasel).

PROCYONIDÆ.

Cercoleptes caudivolvulus (Kinkajou).
Bassariscus astuta (Cunning Bassaris).

URSIDÆ.

Ursus malayanus (Malayan Bear).

Order UNGULATA.

SUIDÆ.

Dicotyles tajaçu (Collared Peccary).

BOVIDÆ.

Oryx Beatrix (Beatrix Antelope).
Gazella arabica (Arabian Gazelle).
Tetraceros quadricornis (Four-horned Antelope).
Ovis tragelaphus (Barbary Wild Sheep).

PROCAVIIDÆ.

Hyrax capensis (Cape Hyrax).

Order RODENTIA.

MURIDÆ.

Pachyuromis duprasi (Fat-tailed Desert Mouse).

MYOXIDÆ.

Myoxus avellanarius (Dormouse).

CASTORIDÆ.

Castor fiber (European Beaver).

SCIURIDÆ.

Sciurus variegatus (Red-bellied Squirrel).
Cynomis ludovicianus (Prairie Marmot).

LAGOSTOMIDÆ.

Chinchilla laniger (Chinchilla).

DASYPROCTIDÆ.

Dasyprocta aguti (Golden Agouti).

Order MARSUPIALIA.

PHALANGERIDÆ.

Trichosurus vulpecula (Vulpine Phalanger).
Petaurus breviceps (Short-headed Phalanger).
Dromicia nana (Dormouse Phalanger).

II. AVES.

PASSERIFORMES.

CORVIDÆ.

Gymnorhina leuconota (White-backed Piping Crow).

FRINGILLIDÆ.

Cardinalis virginianus (Cardinal Grosbeak).

STURNIDÆ.

Acridotheres tristes (Common Mynah).
Grœcula intermedia (Larger Hill Mynah).

COLUMBIFORMES.

COLUMBIDÆ.

Scardafella squamosa (Scaly Ground Dove).

PSITTACI.

PSITTACIDÆ.

Platicercus pollidiceps (Pale-headed Parrakeet).
Psittacus erithacus (Gray Parrot).
Agapornis pullaria (West African Lovebird).

LORIIDÆ.

Lorius domicella (Purple-capped Lory).

RAPTORES.

FALCONES.

Falco elenoræ (Elenora Falcon).
Circaëtus gallicus (Short-toed Eagle).
Gypohierax angolensis (Angolan Vulture).
Milvus ægyptius (Egyptian Kite).
Milvus ictinus (Common Kite).
Tinnunculus alaudarius (Kestrel).
Tinnunculus rupicolus (South African Kestrel).

SARCORHAMPHIDÆ.

Sarcorhamphus gryphus (Condor Vulture).

SYRNIINÆ.

Asio otus (Long-eared Owl).

STRIGIDÆ.

Stryx flammea (Barn Owl).

HERODIONES.

ARDEIDÆ.

Nycticorax griseus (Night Heron).

CICONIIDÆ.

Dissura maguari (Maguari Stork).
Mycteria americana (American Jabiru).

IBIDIDÆ.

Eudocimus albus (White Ibis).
„ „ (2nd specimen).

ALECTORIDES.

GRUIDÆ.

Balearica pavonina (Crowned Crane).

RALLIDÆ.

Porphyrio calvus (Indian Porphyrio).

GALLIFORMES.

TETRAONIDÆ.

Callipepla californica (Californian Quail).
Ortyx virginianus (Virginian Colin).

LIMICOLIFORMES.

CHARADRIIDÆ.

Hæmatopus ostralegus (Oyster-Catcher).

LARIDÆ.

Larus argentatus (Herring Gull).

PYGOPODIFORMES.

PODICEPIDÆ.

Tachybaptes fluviatilis (Little Grebe).

URIADÆ.

Uria troile (Guillemot).

LAMELLIROSTES.

CYGNIDÆ.

Cygnus atratus (Black Swan).

CRYPTURI.

TINAMIDÆ.

Crypturus tataupa (Tatuapa tinamou).

STRUTHIONES.

STRUTHIONIDÆ.

Struthio camelus (Ostrich).

II.—General Observations on the Thyroid and Parathyroids in Mammals.

Before passing to the special accounts of the glands in the various animals some general remarks on the thyroid and parathyroids in mammals will be prefixed. A similar introduction concerning birds will be reserved until that group is under consideration.

1. *Position, etc., of the Thyroid in Mammals.*—The thyroid gland, which is invariably present, lies on either side of the anterior[1] part of the trachea,

[1] The terms "superior," "inferior," "anterior," "posterior," which have been used in the paper on the Human Parathyroids (5) in conformity with the custom of human anatomists, are here replaced by "anterior," "posterior," "ventral," "dorsal," respectively, following the practice of comparative anatomists.

and as a rule overlaps the posterior end of the larynx. The lobes vary considerably in shape, but usually present a convex external or lateral surface and a concave internal or tracheal surface. They are pale or dark brown in colour, and much more regular in outline than in man. They may or may not be connected by an isthmus, but this process is variable even in the same species. The lobes are usually of equal size, but one or other may be the larger. Not uncommonly they are prolonged posteriorly as a tail-like process running in the interval between the trachea and œsophagus. Accessory thyroids are found in many animals. Occasionally colloid cysts are met with.

2. *Number, Position, etc., of Parathyroids.*—Isolated glands possessing a parathyroid structure were found in most but not in all the members of the series. When present their total number was two, three, or four; but these numbers were exceeded in certain specimens. A two-spotted paradoxure (*Nandinia binotata*) and a fossa (*Cryptoprocta ferox*) each had six; a Green Monkey (*Cercopithecus callitrichus*) eight, and a collared Fruit Bat (*Cynonycteris collaris*) ten. As will be explained immediately, there was often great difficulty in deciding whether a particular gland was to be called accessory thyroid or parathyroid.

The parathyroids can scarcely be said to possess any definite anatomical relations, so widely do their positions vary. The commonest site of occurrence was on the convex lateral surface of the thyroid; but they were also found on the tracheal surface, or sunk in the thyroid either deeply or just beneath the capsule or in the immediate neighbourhood of the thyroid, either dorsal, anterior, posterior or external to it, or some distance remote, either isolated or in association with accessory thyroids or lymphatic glands.

They present no naked-eye feature by which their identity can be established; and over and over again in this series they have been found unexpectedly on microscopical section. Those examples which have been attached to lymphatic glands or accessory thyroids have often been quite minute, and frequently glands too small for macroscopic identification have been found attached to the capsule of the thyroid on serial section being made of the whole.

The total volume of parathyroid tissue bears no constant relation to the total volume of thyroid tissue.

3. *Structure of the Thyroid.*—The structure of the thyroid is sufficiently well known to require no detailed attention here. From the enveloping connective-tissue capsule trabeculæ pass through the gland, dividing it into a series of polygonal compartments, each of which encloses a vesicle consisting of a single layer of regular cubical epithelial cells arranged round a

central cavity containing colloid. Bloodvessels and lymphatics run in the trabeculæ.

So far as the connective-tissue framework and the vessels are concerned, this description holds good for all the animals in this series. It is in the contents of the compartments that differences appear. In most mammals these contents conform to the account already given, but frequently the chambers are found to be occupied by solid masses of polygonal cells whose protoplasm may be clear, not staining with acid dyes, or may be full of oxyphile granules. Types intermediate between these extremes are readily found.

A chamber thus filled may be found standing alone amid an uninterrupted expanse of vesicles, or may form one of a small collection, as in a specimen of the Spotted Ichneumon (*Herpestes auropunctatus*). Sometimes an appreciable proportion of a section is occupied by these polyhedral cells, as in the Sumatran Civet (*Viverra tangalunga*), while occasionally glands were found in which these masses considerably exceeded in total area the thyroid vesicles: such was the case with the Arabian Gazelle (*Gazella arabica*) and the European Beaver (*Castor fiber*). In the Fat-tailed Desert Mouse (*Pachyuromis duprasi*) the whole thyroid was made up of those unarranged cells.

Not infrequently there could be noticed among the cells of a compartment a distinct attempt to become grouped round a central lumen; and according to the extent of the transformation, so the cells were found to lose their polyhedral shape and approximate to the regular cubical type. As will be shown immediately, these masses of polyhedral cells are similar in structure to those composing the parathyroids; and since accessory thyroids may show the same variations of structure as the parent gland, the difficulty already referred to of selecting the correct term, "thyroid" or "parathyroid," to apply to these bodies is obvious. As a matter of practice the tissue, thyroid or parathyroid, which predominated decided the question, but an organ which was anatomically the thyroid was always regarded as thyroid even though its structure was that of a parathyroid.

Cells, similar to the polyhedral cells just described and presenting the same variations in appearance, were frequently found lying between the vesicles. They occurred either singly or in small clusters, and will be referred to as interstitial or parathyroid cells. They possess the same characters as the cells of a parathyroid as regards shape, nucleus, protoplasm and oxyphile granules.

4. *Structure of the Parathyroids.*—The connective-tissue elements of the parathyroid are planned on the same lines as those of the thyroid but on a more delicate scale. A thin capsule gives off fine trabeculæ which

divide the whole gland into polyhedral compartments. The bloodvessels and lymphatics run in this framework.

The compartments are all, or nearly all, filled with solid masses of polygonal cells whose protoplasm may be pale and clear or filled with oxyphile granules, or intermediate between these extremes. Often the cells may be seen to have begun to arrange themselves around a lumen filled with a drop of colloid, and thus a primitive vesicle is formed. Occasionally a perfectly formed vesicle, lined by a single layer of regular cubical epithelium and containing colloid, is met with. Colloid also occurs among the polyhedral cells even when no attempt at orderly arrangement is evinced, and in some specimens this secretion may be seen in large masses distending lymphatic vessels.

Finally, a few small isolated glands from the neighbourhood of the thyroid were found to be vesicular on the surface but parathyroidal beneath. Such have been reckoned, not as accessory thyroids, but as parathyroids.

Primates.

Eight specimens of this order, representing five species, were examined. In the Black Ape there was on each side one parathyroid and one accessory thyroid, the latter corresponding to each other in position. The tissue of the left parathyroid was in places directly continuous with that of the thyroid. The White-collared Mangabey showed two parathyroids and Campbell's Monkey one on each side. The Pig-tailed Monkey possessed on the right two parathyroids, one at the posterior pole of the thyroid and one at the centre of the lateral surface; and on the left two, one at the middle of the lateral surface, the other posterior to the thyroid. Behind the right lobe an accessory thyroid lay between the trachea and the œsophagus. Three specimens of the Green Monkey differed notably from each other. In the first the only parathyroid found was buried in one thyroid lobe; in the second, one accessory thyroid and eight parathyroids were found, two on the right lobe, three on the left, and three in the neighbouring connective tissue; the third specimen had one accessory thyroid on the right and two on the left, one of the latter being associated with a parathyroid.

Black Ape (*Cynopithecus niger*).

The thyroid lay on either side of the anterior part of the trachea, the lobes being connected across the 5th and 6th rings by a thin, transparent isthmus 2 mm. broad. The right lobe, which tapered somewhat anteriorly, disclosed a large cyst occupying its posterior quarter. Three smaller cysts were seen on the tracheal surface. A pale-coloured parathyroid lay on its lateral surface near the anterior pole, while half-way along the ventral border was an accessory thyroid. An artery

ran to the posterior pole and a second entered on the dorsal part of the tracheal surface, one-third down the lobe.

The left lobe was shorter and thicker than the right, and contained no cysts. There was an accessory thyroid in a position corresponding to that on the right and a parathyroid on the posterior part of the tracheal surface.

Microscopical Appearances.—Thyroid and accessory thyroid: Arrangement of connective tissue normal. The structure was vesicular throughout, but many of the follicles were irregular in outline (compressed, triangular, tri-radiate, or stellate), and all were lined with tall columnar epithelium. The colloid was scanty and granular, and many vesicles contained nucleated cells. A few interstitial cells lay between the vesicles.

The parathyroids consisted of irregularly arranged columns and clumps of cells. There were no vesicles and no colloid. The left parathyroid was imperfectly cut off from the subjacent thyroid tissue, with which it was in places directly continuous.

Green Monkey (*Cercopithecus callitrichus*).

Specimen No. 1.—The thyroid gland was made up of two elongated ovoid bodies lying in the usual position. No isthmus connected the lobes. A parathyroid was found in the centre of one lobe, but none appeared on the surface.

Microscopical Appearances.—The thyroid was divided in the usual way by connective tissue septa. It was vesicular throughout, the vesicles being lined by regular cubical epithelium and containing colloid. There were very few interstitial cells between the vesicles. At the posterior pole of one lobe, beneath its capsule, was found a clump of lymphoid tissue.

The parathyroid consisted of a mass of polygonal cells with a supporting connective tissue framework in which many bloodvessels ramified. There was no attempt at vesication. For the greater part of its circumference it was isolated from the circumjacent thyroid tissue, but at one part this barrier was absent and the two tissues were directly continuous.

Specimen No. 2.—The thyroid was of peculiar shape. Each lobe lay at the side of the trachea covering the posterior third of the thyroid cartilage, the cricoid cartilage, and the first six tracheal rings. A narrow isthmus connecting the lobes spanned the trachea at its third ring. The posterior extremity of each lobe was prolonged into a tail of greater length than the lobe itself, reaching as low as the 16th ring, and being thinner and more diffuse than the thyroid proper. These tails were united about the 12th ring by a second isthmus (Pl. I. fig. viii.).

An accessory thyroid gland was found in the immediate neighbourhood of the thyroid gland.

Parathyroids.—Altogether eight parathyroids were discovered—two on the right thyroid, three on the left, and three in the connective tissue between the thyroid lobes and the carotid vessels. Of those on the right, the larger was situated at the anterior pole of the thyroid, the smaller half-way along its tracheal surface. The three on the left lay one at each pole, and the other at the middle of the dorsal border.

Microscopical Appearances.—Thyroid: The greater part of the section showed normal thyroid structure—vesicles lined by cubical epithelial cells and filled with colloid—but there was much interstitial or parathyroid tissue. This latter occurred either as a small collection of a few cells between vesicles, or as larger masses of cells, or as extensive areas free of vesicles, but in each case directly continuous with

the thyroid tissue (*i.e.* not encapsuled by connective tissue). In a few examples the parathyroid cells showed some slight attempt at vesicle-formation.

The colloid itself, for the most part homogeneous, was here and there granular.

The accessory thyroid showed similar characters to the parent gland.

In all eight parathyroids the cells were massed irregularly without any definite formation, but they showed varying degrees of activity. Five of them were in full activity, the cells being large, with granular protoplasm which was strongly eosinophile. Two were resting, their cells being smaller, staining only feebly and with no granularity. In one the majority of the cells were resting, but a few active areas occurred.

One of the active glands was attached to a lymphatic gland, and showed a large mass of colloid in one of its lymphatics, while another parathyroid had attached to it a small nodule of lymphoid tissue.

Specimen No. 3.—The thyroid was in its usual position, and each lobe, which was small in comparison with the size of the animal, tapered slightly towards its posterior pole. The two lobes were united across the trachea by a broad thin isthmus, and the left was prolonged posteriorly into a short tail of connective tissue terminating in a pale gland (? parathyroid, but specimen lost).

When the thyroids were removed there appeared on the right side one, and on the left two accessory thyroids lying on the carotid vessels, and one of the latter had a small parathyroid on its surface.

Microscopical Appearances.—The thyroid showed the usual structure, with a fair number of interstitial cells, and the accessory thyroids differed in no way histologically from the main gland.

The parathyroid consisted of a mass of polyhedral cells.

White-collared Mangabey (*Cercocebus collaris*).

The thyroid lay in the normal situation, broadening out posteriorly. On the lateral surface of one lobe close to the anterior pole a parathyroid was found. A second was placed close to the posterior pole.

Microscopical Appearances.—Thyroid: Usual connective-tissue compartments. The whole organ was vesicular, the follicles lined by regular cubical epithelium, and containing colloid, often granular. Very few interstitial cells lay between the vesicles except where the latter were very small, but even here they were limited in number.

The parathyroid cells were arranged without order for the most part, but here and there showed a distinct approach to vesicular grouping. No colloid was found

Campbell's Monkey (*Cercopithecus Campbelli*).

The thyroids occupied a somewhat unusual position. The lobes broadened anteriorly and ran much farther forward than is customary, extending up on each side of the larynx so that their upper ends lay under shelter of the lower jaw. There was no isthmus, but each lobe was continued backwards for about 1·5 cm., the prolongation showing alternating light and dark bands corresponding to the rings of the trachea, and produced by pressure of the latter on the former.

The right lobe showed a parathyroid on its lateral surface as a pale circular area flush with the thyroid. The left lobe showed no corresponding gland, but just

anterior to the junction of the thyroid with its prolongation on its ventral border appeared a parathyroid (Pl. I. fig. x.)

Microscopical Appearances.—The thyroid presented the usual structure, with a varying number of interstitial cells; in some places they were absent, in others they were present in clumps.

The parathyroids showed the usual structure, the protoplasm of the cells being faintly granular.

PIG-TAILED MONKEY (*Macacus nemestinus*). (Age at least 16 months.[1])

The thyroid gland occupied the usual position, and there was no isthmus. The right lobe was somewhat peculiar in shape, tapering anteriorly to a blunt extremity, but widening behind to give a triangular outline. The left lobe was quadrilateral in shape.

A small accessory thyroid, dark in colour, came into view when the right lobe was removed, lying in the interval between the trachea and œsophagus.

Half-way along the lateral surface of the right lobe, deeply sunk in it but easily dissected off, lay a parathyroid pale in tint. At the posterior extremity of the dorsal margin a second parathyroid, bilobed, lay embedded in fat.

About the centre of the lateral surface of the left lobe was a parathyroid similar to the one on the right, while a second parathyroid appeared in the connective tissue a short distance behind the posterior pole.

Microscopical Appearances.—The thyroid was vesicular in structure. At the surface of the gland the vesicles were all large, lined with cubical epithelium, and filled with homogeneous colloid, and no interstitial cells were present. Deeper, however, the vesicles, though of similar structure, were small, and were separated from each other by a considerable number of interstitial cells. In many instances the connective-tissue compartments were filled with solid masses of these cells, there being no central cavity and no colloid.

The accessory thyroid resembled the main gland in structure.

The parathyroids presented the customary features.

CHIROPTERA.

Only one example of this order was examined—a Collared Fruit Bat. In this animal certain parts of the thyroid gland had definite parathyroid structure. The left lobe showed one large and three small parathyroids superficial to its capsule, and in the centre of the right lobe was a mass with exclusively parathyroid characters isolated by connective tissue, and another on the capsule. Four lymphatic glands lying in close proximity to the thyroid lobes all showed parathyroid tissue attached to their surfaces.

COLLARED FRUIT BAT (*Cynonycteris collaris*). (Age 7 years and 3 months.)

An elongated oval, each lobe of the thyroid lay against the anterior part of the trachea with no connectant isthmus. On the right side, lateral to the thyroid,

[1] The ages of most of the animals were not obtainable. When the duration of captivity is known, the period is given prefixed by the words "age at least."

lay two lymphatic glands side by side, the posterior pole of the internal one being pale and white. On the left side were two similar lymphatic glands, the median one being in contact with the thyroid.

Microscopical Appearances.—The thyroid, divided by connective tissue in the usual manner, was composed of small vesicles of uniform size, which were lined by regular cubical epithelium and filled with colloid. In some compartments there was no central cavity, the cells being aggregated into solid clusters as in a parathyroid. In certain parts the whole appearance was that of a parathyroid gland, vesicles being completely absent. Embedded in the centre of the gland and isolated by connective tissue was a mass of cells which were indistinguishable from a parathyroid. Another small parathyroid lay on the surface of the gland. Each of the lymphatic glands showed on section small clumps of parathyroid tissue attached to the surface of the capsule.

The left lobe of the thyroid showed the same peculiarities of structure as the right. Depressed on its surface and enveloped in the same capsule was a fair-sized parathyroid, while three minute clusters of parathyroid tissue were found superficial to the capsule. Each lymphatic gland showed parathyroid tissue on its surface.

Carnivora.

Eighteen examples of carnivorous animals, representing fifteen species, were examined.

Of the Felidæ, the Serval showed one parathyroid on each side, not corresponding to each other in position, and the Fossa (Pl. I. fig. iv.) five parathyroids and an accessory thyroid on the left, and one parathyroid attached to an accessory thyroid on the right. Five out of the six parathyroids contained colloid.

The family of Viverridæ (small cats) afforded seven representatives. The African Civet Cat had one parathyroid on each side, and the cells of one of them showed a distinct tendency to form vesicles. The Sumatran Civet was without any parathyroid proper, but the structure of the thyroid was as much parathyroid as thyroid. The Feline Gennett presented no parathyroid on the surface of the thyroid, but deep in the centre of one lobe was an isolated parathyroid, which contained one or two vesicles containing colloid. Three specimens of the Two-spotted Paradoxure differed strikingly from each other. The first showed three parathyroids on the right and one on the left, while both lobes of the thyroid itself had the histological features of a parathyroid except under the capsule, where ordinary thyroid vesicles abounded, and also in the centre of the right gland, where a mass of typical thyroid tissue occurred. The second specimen had no parathyroids, and the thyroid showed the usual follicular structure, with clusters of interstitial or parathyroid cells in those situations where the vesicles were smallest. In the third specimen six parathyroids were found—three on a side—and the thyroid had much the same structure

as the last specimen. The Malayan Paradoxure had no parathyroid on either side, but the majority of the compartments of the thyroid were filled with masses of parathyroid cells, especially near the posterior pole of the right, where vesicles were entirely absent. Slight attempts at the formation of follicles were not rare. Of a couple of Spotted Ichneumons the first had no parathyroid, the second three (two on one side). The former had a normal thyroid with a few clusters of parathyroid cells, but the second presented extensive areas with parathyroid features, though many fields were made up of ordinary thyroid follicles. The Suricate, with one parathyroid on each side, had a thyroid almost wholly parathyroid in structure, but at rare intervals. least infrequent at the surface, occurred small vesicles. Colloid filled these, and also lay in drops among the parathyroid cells.

The Spotted Hyæna (Pl. I. fig. vii.) possessed a thyroid with very unequal lobes each with cysts, and only the left had a parathyroid. The Side-striped Jackal had a single mass of parathyroid tissue embedded in each thyroid lobe directly continuous with the surrounding thyroid tissue; in addition a parathyroid lay on the surface of the left lobe. In the Weasel no parathyroid was discovered, and the thyroid, though chiefly vesicular, had some compartments with parathyroid attributes, and others intermediate in type between thyroid and parathyroid.

The family of Procyonidæ were represented by the Kinkajou and the Cunning Bassaris (Raccoon). In the former the thyroid was deeply placed against the œsophagus dorsal to the trachea, and each lobe was accompanied by a parathyroid, one of the latter containing colloid in lymphatic spaces. The Raccoon with no parathyroid on the left, though possibly some on the right (*vide infra*), showed a peculiar thyroid whose vesicles had convoluted walls and were filled with much colloid, which was also found occupying lymph channels.

Cystic swellings were the most noticeable naked-eye feature of the thyroid of the Malayan Bear, and they occurred freely throughout both lobes (Pl. I. fig. ix.). Parathyroids, bright yellow in colour, were found to the number of three on the left and one on the right. In addition, a fourth glandular body, paler than the thyroid, less yellow than the parathyroids, was found in connection with the left lobe, and its sections proved to be as much thyroid as parathyroid. The microscopical appearances of the thyroid were remarkable, partly for the duplication of the secreting membranes of the vesicles, partly for the alternation of areas of large vesicles with a fair number of interstitial cells with areas of minute vesicles with quantities of these cells.

SERVAL (*Felis serval*).

The thyroid lobes lay in the usual position, and were not united by any isthmus. The right lobe was pear-shaped, tapering posteriorly, while the left was more slender and slightly larger.

One parathyroid was found in contact with each lobe—on the right at the junction of the middle and lower thirds of the dorsal border, on the left near the anterior pole one quarter along the dorsal border.

Microscopical Appearances.—The thyroid was made up of a mass of small, evenly-sized vesicles lined by regular cubical epithelium, and only a few had any colloid content. Between the vesicles were a few interstitial cells.

The parathyroids were normal.

FOSSA (*Cryptoprocta ferox*). (Age at least 14 years.)

The thyroid stretched from the posterior limit of the larynx back for 16–18 rings. There was no isthmus, and each lobe was brown, diffuse, and very soft in texture. Both lobes tapered considerably towards their posterior ends, and the left was prolonged as a diffuse tail of connective tissue, containing four small collections of parathyroid tissue (Pl. I. fig. iv.).

No parathyroid was seen on the surface of the lobes.

On the right carotid artery at the level of the middle of the thyroid gland appeared a pale, elongated, accessory thyroid divided by two shallow constrictions and having perched on its anterior pole a small parathyroid. On the left side, in a corresponding position, was a smaller accessory thyroid almost wholly occupied by a cyst, and just anterior to it a small parathyroid.

Microscopical Appearances.—The thyroid was made up of vesicles lined generally by cubical cells, but often by flattened cells, and containing much colloid. Colloid was also found in irregular spaces between the vesicles. In those areas where the vesicles were lined by flattened cells interstitial cells were entirely absent, but in other parts they occurred in small amount. The sections were those of a gland in active secretion. In one or two places the appearance to be noted below as regards the thyroid of the Malayan Bear was observed, namely, small vesicles lying immersed in the colloid of a large vesicle.

Both the accessory thyroids contained large cystic collections of colloid.

The structure of the parathyroids presented nothing peculiar. The cells were large, and stained well with eosin. The four parathyroids in the tail of the left lobe were all active. Three of them contained a considerable amount of colloid, and one consisted of a large mass of colloid with comparatively little parathyroid tissue around. The parathyroid attached to the right accessory thyroid showed a large collection of colloid.

AFRICAN CIVET CAT (*Viverra civetta*). (Age at least 7½ years.)

The thyroid lobes were connected across the 3rd and 4th tracheal rings by a very narrow isthmus arising from the extreme posterior pole of the left lobe, but somewhat more anteriorly from the right. The left lobe showed a depression in the posterior third of its lateral surface, in which lay a white coloured parathyroid gland bound down by connective tissue. The right lobe showed no body in the corresponding position, but in the connective tissue 2–3 mm. anterior to the oral pole of the thyroid was a white-coloured parathyroid (Pl. I. fig. v.).

Microscopical Appearances.—The vesicles of the thyroid varied much in size, were lined by regular cubical epithelium, and contained colloid. There were many clusters, large and small, of interstitial cells.

The parathyroid on the left showed the usual structure, but in that of the right there was a distinct tendency for the cells to be arranged in concentric manner (not, however, enclosing colloid), their shape being more or less cubical.

SUMATRAN CIVET (*Viverra tangalunga*). (Age at least 3½ years.)

Each thyroid lobe lay in the usual site, and was elongated and irregular in shape, tapering towards its posterior pole. A narrow isthmus joined the extreme posterior poles (Pl. I. fig. vi.).

No parathyroid or accessory thyroid was found.

Microscopical Appearances.—The thyroid consisted of as much parathyroid tissue as thyroid tissue. There was a number of vesicles of varying size, filled some with homogeneous, some with granular colloid, and all lined with perfectly regular epithelium. Between the vesicles was a considerable amount of parathyroid tissue, the cells arranged for the most part without order, but often showing an attempt at concentric formation. Here and there between the parathyroid cells were droplets of colloid.

FELINE GENNETT (*Genetta felina*). (Age at least 18 months.)

The thyroid occupied the usual position and no parathyroid was found, except one in the centre of one of the thyroid lobes.

Microscopical Appearances.—Only one thyroid lobe was examined. On section it was seen to be made up of vesicles lined by regular cubical epithelial cells and containing colloid. In places the vesicles were very small, but at the surface they were for the most part large. A few interstitial cells were scattered through the sections, and were most numerous between the smallest vesicles.

Sections passing through the centre of the gland disclosed a parathyroid deeply embedded. It presented the usual histological features — a connective tissue compartition supporting clumps of polyhedral cells staining brightly with eosin, but was of interest because of the presence of one or two vesicles containing colloid.

TWO-SPOTTED PARADOXURE (*Nandinia binotata*).

Specimen No. 1 (age at least 18 months).—The thyroid occupied the usual position. Its lobes were connected across the trachea by a narrow isthmus, and each was prolonged posteriorly into a fine tail of diffuse texture, that on the left terminating in a small lymphatic gland.

On the lateral surface of the right lobe one-third the way along the dorsal border lay a small parathyroid. A second parathyroid projected from the same border near the posterior pole, while the tail was made up of parathyroid tissue. The left lobe showed one-third along the dorsal border a parathyroid, pale in colour like the others.

Microscopical Appearances.—The thyroid was made up of absolutely typical parathyroid structure, the cells being massed together with no attempt at order. On the surface of the gland, however, there was definite conversion into vesicular thyroid tissue, the follicles being lined with regular cubical epithelium and filled

with homogeneous colloid. Over the greater extent of the surface these vesicles were only one layer deep, but in places they penetrated farther into the gland. In the centre of the right gland, wholly buried, was a mass of typical thyroid tissue with, however, many interstitial cells between the vesicles. This clump, which was distinguishable even to the naked eye, was directly continuous with the parathyroid tissue around, no connective tissue being interposed.

The parathyroid bodies were similar in appearance, being composed of masses of polyhedral cells with much granular protoplasm staining well with eosin.

Both thyroid lobes showed the same features, but there was no central clump of thyroid tissue in the left.

Specimen No. 2.—The thyroid filled the usual position. No parathyroid gland was found.

Microscopical Appearances.—The thyroid consisted of vesicles lined by regular cubical epithelium and containing colloid. In a few vesicles the epithelium was more nearly flattened. Certain areas showed the epithelium of adjacent vesicles separated only by the finest layer of connective tissue, but the majority of the fields revealed a varying number of interstitial cells. These clusters varied in size, being largest and most frequent where the vesicles were smallest. At the surface of the gland, where the vesicles were big, the clusters were rarest, and in many places completely absent. The lining cells, in the largest follicles especially, tended to a flattened type. Near the centre of the gland was a large mass of colloid in a cavity lined by definitely flattened epithelium (*i.e.* a lymphatic vessel).

Specimen No. 3 (age at least 18 months).—The thyroid lobes were situated as in the previous specimens and were connected by an isthmus. The right showed a whitish parathyroid attached loosely to its lateral border about one-third from the anterior end. From its posterior pole grew an elongated tail of connective tissue which contained near its end another whitish parathyroid. Close to the posterior pole and ventral to the carotid artery lay a third parathyroid, differing from the others, however, by its yellow hue.

The left lobe presented a parathyroid near the anterior extremity of the lateral border. A connective-tissue tail similar to the one on the right terminated in a second parathyroid, while a third was found near the posterior pole.

Microscopical Appearances.—The thyroid showed the usual vesicular structure, with a fair number of interstitial cells. The larger collections of colloid near the surface were contained in spaces lined by distinct flattened endothelium (*i.e.* lymphatic vessels.)

The parathyroids presented the customary features.

Malayan Paradoxure (*Paradoxus hermaphroditus*).

The thyroid lobes occupying the usual position were not united by an isthmus.

No parathyroid could be found.

Microscopical Appearances.—The thyroid was divided into compartments by connective tissue, but a somewhat curious appearance was given to the sections in places, owing to the isolation of areas by thick trabeculæ, whereby a lobular structure was conferred on the gland. Many of the compartments were lined by regular cubical epithelium enclosing colloid, but the greater number showed an irregular massing of cells as in a parathyroid. Near the posterior pole of the right thyroid the vesicles were completely absent, and the structure was typical of a parathyroid without colloid. This area was directly continuous with the thyroid proper. A

second similar area was seen on section of the left thyroid at the surface of the gland.

In certain of the compartments where, as already mentioned, the cells were irregularly massed an attempt at the formation of a definite lining epithelium could be traced.

SPOTTED ICHNEUMON (*Herpestes auropunctatus*).

Specimen No. 1.—The thyroid lobes call for no comment beyond the fact that they were not united by an isthmus. No parathyroid was found.

Microscopical Appearances.—The thyroid showed the usual vesicular structure, with a few clusters of interstitial cells here and there.

Specimen No. 2.—The thyroid in the usual position possessed no isthmus. Each lobe presented on its lateral surface near the dorsal border a pale-coloured parathyroid flush with the main gland. One lobe (? left) showed further a small parathyroid buried deeply.

Microscopical Appearances.—The thyroid showed a structure more nearly parathyroid than thyroid in nature. The majority of the compartments were filled by polygonal parathyroid cells with no attempt at regular arrangement or the formation of central cavities. Other compartments, constituting a fair proportion of the whole, possessed a definite lining of cubical cells and a central lumen containing colloid either granular or homogeneous, but extensive areas were readily found in which there was no suspicion of thyroid structure, the whole field being typically parathyroid.

The parathyroids themselves were wholly embryonic and yet differed from the main gland in certain respects. Their general appearance was paler, owing to the cells being less crowded. The protoplasm of each was considerable, quite pale in tint and slightly granular in texture. The nuclei, oval in shape, were longer and paler than most of those in the thyroid proper, and were made up of a more open chromatin network. These differences between thyroid and parathyroid probably represented different stages in functional development.

Buried in the centre of one lobe was a small cluster of these larger cells, encapsuled from the thyroid around. It appeared in only a few serial sections, as it was made up of not more than a couple of hundred cells.

SURICATE (*Suricata tetradactyla*). (Age at least 9 months.)

The thyroid lobes, oval in shape, were joined by an isthmus. At the anterior extremity of each on the dorsal border was a small parathyroid. Lateral to each thyroid lobe was a bright orange-coloured gland which proved to be lymphatic in nature.

Microscopical Appearances.—Sections of the thyroid revealed fine trabeculæ of connective tissue forming compartments, each filled with a mass of polyhedral parathyroid cells. Rarely, but with greater frequency near the surface, were small areas throughout which the cells had grouped themselves around colloid-containing cavities, and had acquired a cubical shape by mutual pressure. None of these vesicles attained large size. Intermediate types where drops of colloid lay among the irregularly arranged cells were also noted. Further, a few large masses of colloid were found enclosed by a more or less regular layer of cubical cells.

The parathyroids were very similar to the thyroid, but the protoplasm of the cells was paler, and no colloid could be found.

Spotted Hyæna (*Hyæna crocuta*). (Age at least 10 years.)

The thyroid lobes, which were joined by an isthmus across the 4th, 5th, and 6th rings of the trachea, were markedly different in configuration. The right, which was four or five times the volume of the left, was notched at its anterior end, where it received an artery, and its outline somewhat resembled that of a large bean. The isthmus arose by a broad root from the whole of the lower half of its ventral border. The lateral surface of the lobe showed an elevation due to a cyst, and on its tracheal surface were three indistinctly outlined nodules of thyroid tissue. No parathyroid was found (Pl. I. fig. vii.).

The left lobe was long and thin, and the isthmus arose from the posterior extremity, so that the whole presented the appearance of an "L." Two cysts projected from the lateral surface near the posterior pole, and a third was seen on the tracheal aspect. About the middle of this latter surface was a parathyroid distinctly white in colour and separated from the thyroid beneath by connective tissue.

Microscopical Appearances.—Post-mortem changes were marked. The thyroid showed the usual structure, but most of its vesicles were empty. Here and there were large vesicles containing colloid, and not infrequently cysts similarly occupied. Interstitial cells were scattered irregularly throughout the organ.

The parathyroid presented the normal features. The connective tissue, which was fairly abundant, formed coarse trabeculæ dividing the gland into lobule-like portions.

Side-striped Jackal (*Canis lateralis*). (Age at least 3 years.)

The thyroid occupied the usual position. The right lobe was the longer of the two, being prolonged posteriorly into a tapering process. There was no isthmus.

The left lobe showed depressed on its lateral surface a pale parathyroid. In a corresponding position on the right was a curious finger-like process of thyroid tissue. On section a mass of parathyroid tissue was found embedded in each gland, directly continuous, however, with the surrounding thyroid tissue.

Microscopical Appearances.—The lining cells of the thyroid vesicles were cubical and the colloid homogeneous. The walls of the vesicles showed a marked tendency to become convoluted and to project into their lumina.

The parathyroid presented no unusual feature.

Weasel (*Mustela vulgaris*).

The thyroid was somewhat pear-shaped, the tapering end being posterior. There was no isthmus.

No parathyroid was found.

Microscopical Appearances.—The thyroid was permeated by the usual connective-tissue trabeculæ. Many compartments thus formed contained vesicles lined by regular cubical epithelium, and containing homogeneous colloid. In others the cells lay in disorder, while in others again they showed only a tendency to group themselves around a central lumen.

Kinkajou (*Cercoleptes caudivolvulus*). (Age at least 3½ years.)

The thyroid lobes were reached only on deeper dissection than customary, as they lay dorsal to the trachea and in lateral contact with the œsophagus. There was no

isthmus. Each lobe tapered posteriorly and revealed deep to its posterior end a parathyroid yellow in colour.

Microscopical Appearances.—The thyroid was of usual structure, and its vesicles of uniform size and lined with cubical epithelium. The colloid contents were much vacuolated, but this appearance was probably artificial.

The parathyroids possessed the usual structure, and one showed two masses of colloid contained in lymphatics on the surface of the gland.

CUNNING BASSARIS (RACCOON) (*Bassariscus astuta*). (Age at least 5 years.)

The position of the thyroid gland calls for no comment. Its lobes were united about their middles by a thin, delicate isthmus.

No parathyroid was found on the left side. On the right a pale gland was attached to the surface of the thyroid near its anterior pole, and was perhaps a parathyroid, but unfortunately the specimen was lost before being sectioned.

Microscopical Appearances.—Sections of the thyroid presented a striking appearance, owing to the vesicles being either very large or very small, and the former being notably irregular in outline. All the follicles were lined by cubical epithelium, and the gland was in a state of active secretion, as shown by the large amount of colloid present. The large vesicles, instead of being regular in shape, possessed walls which bulged and receded in most irregular fashion, while in many of them the secreting surface was amplified by the projection into the lumen of long and delicate folds of connective tissue bearing on both surfaces cubical secreting cells. This arrangement gave many of the vesicles a lobulated aspect, while in others the appearance was as if there was continuity of colloid between two adjacent vesicles. The small vesicles were all regular in outline (circular or oval), and presented no foldings of their walls. Here and there were lymphatic channels lined by flattened epithelium and containing colloid, one in particular being found split longitudinally for some considerable distance. Interstitial cells were fairly numerous between the small vesicles, but were rare elsewhere.

MALAYAN BEAR (*Ursus malayanus*). (Age at least 18 months.)

The thyroid gland was large in comparison to the size of the animal, and its lobes lay on either side of the lower part of the larynx and the upper six or eight rings of the trachea. They were joined at their posterior ends by an isthmus formed of a broad, flat sheet of thyroid tissue. Their colour was dark brown (Pl. I. fig. ix.).

The left lobe was the longer and larger of the two. Its oral pole was notched and its outline was regular, except for a few local prominences. The two largest of these projected from the dorsal margin, and others appeared on the tracheal surface, on the lateral surface, and on the isthmus. In each case the swelling was found to be caused by cystic formations. On the lateral surface of the lobe lay a parathyroid —a pale, bright-yellow, oval body about 1 cm. in length—and farther back was a second smaller parathyroid, also bright-yellow but bilobed. On the same surface near the anterior pole a minute body was found, yellowish in hue but less so than the parathyroids, though paler than the thyroid tissue proper. This proved to be in structure intermediate between thyroid and parathyroid. A third gland somewhat similar in appearance found in the connective tissue posterior to the lobe proved to be a lymphatic gland.

A considerable part of the anterior pole of the right lobe was occupied by

a large dark-coloured cyst. About the middle of the lateral surface was a bright yellow parathyroid. There were two irregular prominences of thyroid tissue projecting from the dorsal border of the gland.

Microscopical Appearances.—The gland was fixed entire for twenty-four hours and then cut into thin slices, the surfaces of each being carefully examined. No additional parathyroid was found, but the whole gland was seen to contain a large number of colloid cysts of divers sizes.

The microscopical appearances of the thyroid varied considerably in different sections. For the most part it was that of a thyroid composed of large polygonal vesicles lined by regular cubical cells and filled with homogeneous colloid, while in between the vesicles was a fairly large number of interstitial cells. In places occurred clumps of minute vesicles with a considerable amount of interstitial cells admixed, and here the features were as much those of a parathyroid as of a thyroid. Such clumps showed in marked contrast to the more open aspect of the remainder of the sections, and were in some, but not in all cases, isolated by connective tissue.

In many places large irregular masses of colloid occurred between the vesicles, especially where the latter were minute, and these collections of secretion were not contained in any definite follicle, but occupied intercellular spaces. In other places the epithelial walls of the vesicles were markedly convoluted, the folds projecting into the lumen within. Where this condition was marked there was produced the appearance sometimes noted in Graves's disease, where a cluster of colloid-containing vesicles will be found lying in the midst of the colloid content of a large vesicle. In a few instances the colloid, instead of being homogeneous and dark-staining with eosin, was granular and pale.

The whole appearance of the thyroid was that of a gland in very active secretion.

The minute body found on the lateral surface of the left lobe was more parathyroid than thyroid in structure, one end consisting of small, regularly-formed vesicles, the other of parathyroid tissue with a few very minute vesicles.

The parathyroids presented no unusual feature in their structure, except that the amount of connective tissue was excessive compared to that noted in other animals. Large, coarse trabeculæ ran through the gland, and, dividing into finer processes, made compartments enclosing groups of parathyroid cells. These latter, which were of the usual polygonal type, showed no special tendency to stain deeply with eosin.

Ungulata.

Examination was made of six different species of Ungulata.

The Collared Peccary, representing the family of Suidæ or Pigs, was found to possess no parathyroids.

The three examples of the Bovidæ were specially interesting. The Beatrix Antelope, with no isolated parathyroid, showed a thyroid which was entirely embryonic in structure—there was no attempt at vesicle formation and no secretion of colloid. The Arabian Gazelle also, with no isolated parathyroid, showed a curiously-shaped thyroid which possessed a parathyroid structure although a considerable number of vesicles were present. In a Four-horned Antelope the thyroid was remarkably small and its compartments were filled with polyhedral, embryonic-looking cells,

but at a few sites there was a commencing transformation into thyroid follicles. A gland resembling the thyroid and found near the left lobe was composed of similar cells except at the surface, where there was a cortical layer of small thyroidal vesicles.

The Cape Hyrax was found to possess one parathyroid on each side, and its thyroid was unique in that it sent a process between the œsophagus and trachea. In the Barbary Wild Sheep the thyroid was supplemented by two accessory thyroids attached to the thymus at the root of the neck, one of them being of greater volume than both the thyroid lobes together. The structure of all these was for the most vesicular (some follicles had tall columnar cells), but there was much parathyroid tissue. No parathyroid was found.

Collared Peccary (*Dicotyles tajaçu*).

The thyroid was found lying at the side of the trachea covering the first few rings and extending forward to spread over the hind border of the cricoid cartilage. The lobes expanded posteriorly, where they united across the trachea by a narrow isthmus.

Fourteen glands from the neighbourhood were found and examined, but no parathyroid or accessory thyroid was discovered.

Microscopical Appearances.—There was much post-mortem change. The thyroid was vesicular throughout, its follicles being lined with regular cubical epithelium, and containing colloid.

Beatrix Antelope (*Oryx Beatrix*).

On removing the sterno-hyoid and sterno-thyroid muscles the thyroid was seen as a small gland lying at the side of the 2nd, 3rd, and 4th tracheal rings. Each lobe was regularly pear-shaped, the larger end being anterior, and was attached by connective tissue to the side of the trachea. No trace of any isthmus was made out, nor did a minute dissection reveal any glandular body on or near the thyroid gland.

Microscopical Appearances.—Longitudinal sections of both lobes of the thyroid showed a uniform appearance. The whole section was divided by connective tissue into compartments, each of which was occupied by a mass of cells irregularly arranged. Nowhere was there any trace of vesicle formation, and there was no colloid. The sections were indistinguishable from parathyroid tissue.

Arabian Gazelle (*Gazella arabica*).

Each lobe, the site of which conformed to normal, consisted of a head about 2·5 cm. long, passing at the posterior pole into a long tail 4 cm. long on the right and 6 cm. long on the left. The shape of the whole lobe suggested that of a spermatozoon.

No parathyroids were found.

Microscopical Appearances.—Sections through each lobe showed the structure to be for the most part non-vesicular. The gland was divided by thin connective-

tissue strands into compartments, by far the largest number of which were occupied by masses of polyhedral cells. Scattered irregularly, but not very infrequently, were compartments lined by regular cubical epithelium set around colloid. Such vesicles varied in size, but none was of notable diameter. The whole organ was peculiarly vascular: in many places there were areas consisting solely of spaces filled with red corpuscles.[1]

It is not possible to say whether the sections are those of a thyroid with parathyroid characteristics or of a parathyroid with thyroid features.

FOUR-HORNED ANTELOPE (*Tetraceros quadricornis*). (Age 1 month.)

The thyroid lobes were small and lay on either side of the trachea, their posterior ends being united by an isthmus. At the posterior pole of the left lobe were two translucent bodies not found on the right side (*vide infra*).

The gland was of a very pale brown, almost white, colour, and its lobes showed no irregularity of outline. The tracheal surface was concave to fit against the windpipe, and the lateral surface convex, with no prominences or fissures. The most noteworthy point in its naked-eye appearance was its remarkably small size compared to that of the whole animal.

Microscopical Appearances.—Sections through the whole length of each gland revealed the following characteristics:—

The gland was enveloped in a connective-tissue capsule, and its substance was divided into compartments by a delicate meshwork of trabeculæ, in which were the smaller bloodvessels and capillaries. Each compartment was filled with embryonic-looking cells, polyhedral in shape, with a considerable amount of faintly granular protoplasm staining readily with eosin, and with nuclei circular or oval.

In addition to this uniform structure there was to be seen in a few places the commencing change of this embryonic tissue into mature thyroid tissue. This transformation was seen to begin as an increase of the eosinophile affinity of the cells occupying a compartment. A small space filled with a coarsely granular, pale-staining secretion then appeared in their midst, and around it the cells, still polygonal in shape, became grouped in layers two or three deep. Later, this space gradually enlarged and the cells became more regularly arranged, until finally they formed a single layer next the connective tissue wall and enclosed a circular or oval central cavity. By mutual pressure these cells lost their polyhedral outline and became regularly cubical. The central cavity was finally occupied by a drop of homogeneous colloid.

In the young antelope examined, only a very small part of the total gland had lost its embryonic character, but the change had gone far enough to allow all the above changes to be followed.

Of the two translucent bodies mentioned above, one was mislaid, but the other showed a structure exactly comparable to that of the thyroid. It consisted of similar compartments filled with polyhedral cells, but the conversion to thyroid structure was more advanced, though it was limited to the cortical regions of the gland. Almost the entire circumference showed a cortex of thyroid vesicles, in some places as many as six or eight deep, and the transformation was apparently

[1] Three adjacent glands, presumably hæmo-lymphatic, taken from near the bifurcation of the internal jugular vein, and black and spherical when fresh, presented this marked vascular character.

spreading more deeply into the gland. They were all small, some incompletely formed, and still lined by more than one layer of cells, and with a few exceptions, where the content was homogeneous colloid, contained granular secretion.

Cape Hyrax (*Hyrax capensis*). (Age at least 2 years.)

The thyroid lobes lay at the side of the posterior part of the larynx and first few tracheal rings, and were united near their anterior ends by a narrow isthmus. Each was prolonged in an exceptional manner as a process passing in between the trachea and œsophagus, being firmly attached to the dorsal surface of the former. This arrangement made the removal of the glands particularly difficult. The two processes were united across the middle line by a transversely running vein (Pl. I. fig. i.).

On each side a pale-coloured parathyroid was found lying on the lateral surface, that on the left being at the point of entry of an anterior thyroidal artery, on the right just posterior to this.

Microscopical Appearances.—There was the usual arrangement of connective tissue in the thyroid. Its vesicles, which varied greatly in size, were lined by regularly arranged cells varying in shape from a squat cubicle to a fairly tall columnar. The extreme types were as a rule single cells flanked by the more customary cubical cells. The vesicle contents were either homogeneous or granular colloid, but in many follicles the central part of the secretion was homogeneous, the periphery granular. There was a great number of interstitial cells which were large and polygonal, with much protoplasm, generally granular: they occurred for the most part in large clusters.

The parathyroids were made up of a mass of cells similar to those found in the thyroid clusters. They nowhere presented any definite arrangement, but many capillaries appeared among them. The whole appearance was similar to that of the human parathyroid in an active state.

Barbary Wild Sheep (*Ovis tragelaphus*). (New-born.)

The thyroid lobes, which were small, lay on either side of the trachea and were not united by any isthmic tissue. At the root of the neck was a large thymus gland the anterior end of which was prolonged into two hornlike processes running up the neck ventral to and on either side of the trachea. Sunk in the substance of the median aspect of the left horn was a pale brown accessory thyroid gland measuring 1 cm. by ·5 cm., while deep in order of dissection (*i.e.* dorsal) to the main mass but peeping from beneath it was a second accessory thyroid gland of greater volume than both the thyroid lobes put together (Pl. I. fig. ii.).

No parathyroid was found.

Microscopical Appearances.—The lobes showed for the most part thyroid structure, but there was much parathyroid tissue throughout. Many vesicles, probably the majority, were lined by cubical epithelium, but a large number, especially of the larger ones, showed regular, tall columnal cells. The colloid was more often pale and granular than homogeneous, the latter occurring most frequently in the smaller follicles.

Both the accessory thyroids agreed structurally with the thyroid proper.

Rodentia.

This order is represented by ten specimens comprising seven species.

In the Fat-tailed Desert Mouse the whole thyroid was parathyroid in structure, no vesicles having formed. On the surface of one lobe was an isolated mass of similar structure. The thyroid of a Dormouse, though showing the usual vesicles, had many clusters of interstitial cells. The European Beaver, with an unusually-shaped thyroid, had no isolated parathyroid, and though the main gland was to a certain extent vesicular, this arrangement was exceeded in amount by parathyroid tissue, amid the cells of which colloid frequently occurred. Both the Prairie Marmot and the Chinchilla had thyroids of normal structure, and the latter possessed a parathyroid attached to one lobe. The Golden Agouti with two parathyroids, one on each side, showed on the left an accessory thyroid which, though chiefly thyroidal in nature, was made up at one end of parathyroid tissue.

Fat-tailed Desert Mouse (*Pachyuromis duprasi*). (Age 3 months.)

The anatomical account of this animal was mislaid.

Microscopical Appearances.—Each thyroid consisted throughout of parathyroid structure. The cells, large, polygonal, with granular protoplasm, were arranged in irregular clumps and made no attempt to form vesicles. At intervals a drop of colloid was seen, but never with any definite arrangement of cells around.

On the surface of one thyroid, isolated by connective tissue, was a mass of cells having the appearance of a parathyroid. These cells were somewhat darker than those of the thyroid beneath, but this was due to the comparatively small amount of protoplasm, which resulted in the deep-stained nuclei being more closely apposed.

Dormouse (*Myoxus avellanarius*).

The thyroid was closely attached to the trachea. It was ill-defined in outline, and being of a remarkably soft consistency it is possible some fragment may have been left behind. In any case no parathyroid was found.

Microscopical Appearances.—The thyroid showed the usual follicular structure, but there were many clusters of interstitial cells. At one place there was a clump of large interstitial cells with granular protoplasm staining well with eosin.

European Beaver (*Castor fiber*). (Age at least 2 years.)

The position of the thyroid was normal. Its lobes were roughly globular in shape and less flattened than in most animals. They showed facets on their surfaces where the organ had been impressed by adjacent structures, and were united by a specially long and ribbon-like isthmus slightly indented at its middle (Pl. I. fig. iii.). A large number of glands of varying shape and size were found in the neck, but they all proved to be lymphatic.

Microscopical Appearances.—Sections through the whole lobe showed that

though the structure was that of a thyroid, there was an amount of parathyroid tissue greatly in excess of the thyroid proper. The vesicles, which varied greatly in size, were lined by a beautifully regular cubical epithelium, and contained colloid, either homogeneous or granular, and many gradations between the two were to be found. The parathyroid cells were of the usual type, and in places showed attempted arrangements into vesicles. Drops of colloid occurred frequently between these parathyroid cells.

RED-BELLIED SQUIRREL (*Sciurus variegatus*).

(The animal had been dead for some days before being examined, and post-mortem changes were so marked as to render microscopical examination futile.)

The thyroid was bright pink in colour, and lay on either side of the trachea and thyroid cartilage. A delicate isthmus united the lobes, but the gland was too soft and friable for further examination.

PRAIRIE MARMOT (*Cynomis ludovicianus*).

The thyroid lay at the side of the trachea, scarcely overlapping it at all. There was no isthmus. The anterior poles of the lobes were thin, tapering, and gelatinous.

About a quarter along the lateral margin of the right lobe a pale area was seen. It was minute in size, and was possibly a parathyroid, but was lost in preparation.

Microscopical Appearances.—The connective-tissue trabeculæ of the thyroid were somewhat thick, and in places the gland was infiltrated with fat. (The rodent had died at the end of the autumn, when about to hibernate, and the body showed everywhere a copious deposit of fat.) The general structure was vesicular, with regular cubical epithelium and much colloid. The follicles varied in size, some being small enough to be enclosed by less than a dozen cells; others were large. The anterior pole of one lobe showed only a collection of very large vesicles, the epithelium being either flattened or stunted cubicle. Interstitial cells were few, except where the vesicles were minute.

CHINCHILLA (*Chinchilla lanigera*).

The thyroid extended from the posterior border of the thyroid cartilage to the 7th tracheal ring, and tapered slightly towards the posterior poles. There was no isthmus.

At the junction of the anterior and middle thirds of the internal margin of the left lobe there was a prominence made by a parathyroid gland.

Microscopical Appearances.—The structure of the thyroid was normal. The vesicles were all filled with homogeneous secretion, and much colloid was seen in the lymphatics running in the trabeculæ. Clusters of interstitial cells, large and small, were seen scattered through the gland.

The parathyroid consisted of an irregular massing of cells with a slight suggestion of vesicle formation.

GOLDEN AGOUTI (*Dasyprocta aguti*). (Age at least 5 years.)

The thyroid presented no feature of note. On the surface of one lobe was a parathyroid, and another was found in the centre of the other lobe.

Just below and ventral to the thyroid lobe was a small cyst containing drops of colloid. Ventral to the middle of the left lobe was an accessory thyroid.

Microscopical Appearances.—The thyroid vesicles were lined by the ordinary

cubical epithelium, and contained colloid. A fair number of interstitial cells lay between the follicles. The accessory thyroid showed chiefly thyroid structure, but at one end there were no vesicles, and the cells were arranged as in a parathyroid.

The parathyroid, which was isolated from the thyroid, consisted of solid masses of cells with no vesicles. A second parathyroid was found in the centre of one lobe, where it was isolated by connective tissue and associated with a buried mass of lymphatic tissue.

MARSUPIALIA.

Although three marsupials were dissected, in one the examination was not completed microscopically.

In the Vulpine Phalanger three accessory thyroids were found, one of which was associated with a mass of parathyroid tissue. The Short-headed Phalanger was without either accessory thyroids or parathyroids.

VULPINE PHALANGER (*Trichosurus vulpecula*).

The thyroid calls for no comment. Two millimetres behind its posterior pole lay a small accessory thyroid, disc-shaped, while another similar body lay on the 1st tracheal ring at the side of the trachea. In the connective tissue near the right lobe of the thyroid a third accessory thyroid was found.

Microscopical Appearances. — The thyroid possessed the usual capsule with trabeculæ dividing the whole organ into compartments, most of which contained cubical epithelium grouped around a central cavity; a few, however, showed an irregular arrangement of cells. There was very little colloid.

One of the accessory thyroids presented at one extremity a mass of parathyroid tissue isolated from the rest of the gland by connective tissue.

SHORT-HEADED PHALANGER (*Petaurus breviceps*). (Age at least 3 years.)

The thyroid lobes, which were not united by any isthmus, lay on either side of the anterior part of the trachea, ventral to the carotid vessels but wholly internal to them. To naked-eye examination they were plainly vesicular.

No parathyroid gland was found.

Microscopical Appearances.—Sections of the thyroid showed the usual appearance, most of the follicles being of large size and lined by short cubical (in many cases almost flattened) epithelium, and filled with much colloid. In a few places were groups of very small vesicles. Two or three clusters of parathyroid or interstitial cells were found, but no isolated parathyroid.

DORMOUSE PHALANGER (*Dromicia nana*). (Age at least 4½ years.)

The thyroid was in the usual position and had no isthmus. There was a number of minute glands adjoining the thyroid lobes, but all the specimens were unfortunately lost.

[The table of references will be given at the end of Part II.]

EXPLANATION OF PLATE I.

PLATE I.—Showing types of mammalian thyroid glands.

References—

Acc. T.	accessory thyroid.	*T.*	thyroid gland.
C.	cyst.	*T.C.*	thyroid cartilage.
L.	lymphatic gland.	*Thy.*	thymus.
Oes.	œsophagus.	*Tr.*	trachea.
P.	parathyroid gland.		

Fig. i. Cape hyrax (*Hyrax capensis*), seen from behind, the œsophagus having been thrown forward.
Fig. ii. Barbary wild sheep (*Ovis tragelaphus*).
Fig. iii. European beaver (*Castor fiber*).
Fig. iv. Fossa (*Cryptoprocta ferox*).
Fig. v. African civet cat (*Viverra civetta*).
Fig. vi. Sumatran civet (*Viverra tangalunga*).
Fig. vii. Spotted hyæna (*Hyæna crocuta*).
Fig. viii. Green monkey (*Cercopithecus callitrichus*).
Fig. ix. Malayan bear (*Ursus malayanus*).
Fig. x. Campbell's monkey (*Cercopithecus Campbelli*).

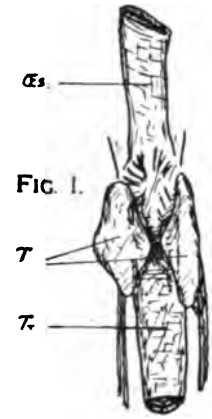


FIG. I.

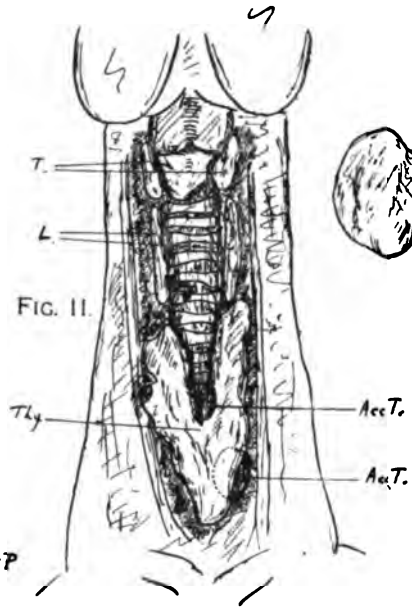


FIG. II.

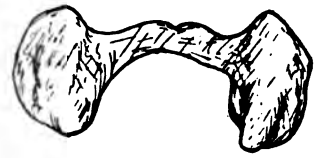


FIG. III.



FIG. IV.

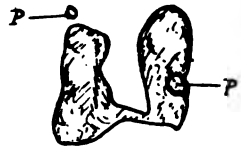


FIG. V.



FIG. VI.

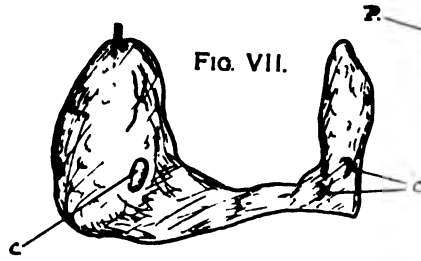


FIG. VII.

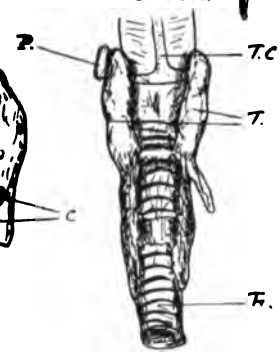


FIG. VIII.

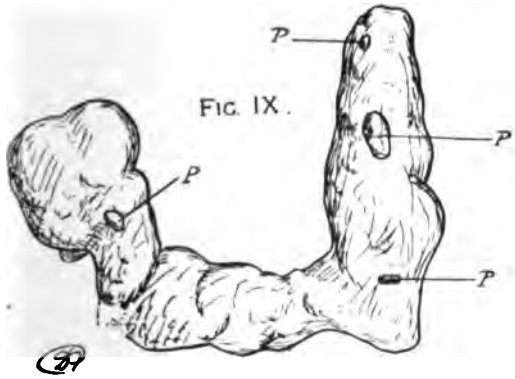


FIG. IX.

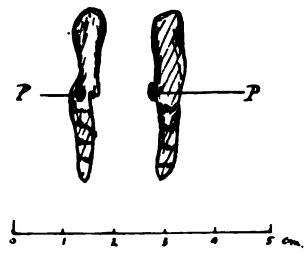


FIG. X.

PLATE I.

A NOTE ON THE DEVELOPMENT OF THE SEPTUM TRANSVERSUM AND THE LIVER.

By PETER THOMPSON, M.D.,
Professor of Anatomy, King's College, London.

IN the description of a human embryo of twenty-three paired somites, which appeared in the April number of the Journal, it was only possible to mention briefly the arrangement of the septum transversum and the liver. In this note it is intended to amplify the account of those structures and to illustrate their form and relations to surrounding organs.

To W. His (1) we owe the first clear account of the septum transversum, and, since the publication of his work, several valuable papers have added to our knowledge of its comparative embryology. One may perhaps mention particularly the work of Ravn (2) on birds and rabbits, Wölfel (3) on ruminants, Lockwood (4), Brachet (5), and Uskow (6) on rabbits, and Robinson (7) on rats and mice; whilst Mall (8), Bromann (9), and others have given us detailed accounts of the development of the diaphragm in man, and have dealt with the arrangement of the septum transversum in embryos of various stages of development.

In the specimen now under consideration, which, it may be recalled, was 2·5 mm. in length, the septum transversum is seen before the cells of the liver bud have invaded the vessels which lie embedded within it. Fig. 1 is a drawing of a model reconstructed by the wax-plate method of a part of the embryo with the heart *in situ*. With the exception of the heart and spinal cord, the model is in sagittal section through the middle line, so that a view is obtained of the right half of the body from within. It shows the arrangement of a thick mesoblastic septum (S.T.) which is continuous cranialwards with the dorsal mesocardium and ventrally with the structure known as the ventral mesentery. The latter is continuous with the ventral body wall opposite the attachment of the root of the amnion. It will be clear, therefore, that the general disposition of the mesoderm here takes the form of an oblique septum, placed between the heart and the alimentary canal, and in front of the umbilical orifice. Leaving out of account the dorsal mesocardium, which subsequently disappears, the oblique septum consists of two parts: (1) a thick mass into which the liver bud is seen to be growing, and (2) the ventral mesentery. It is placed opposite the third and fourth cervical somites.

There is, however, a third part continuous with the septum just described, but not seen in the model, because it is situated on either side of the entodermal tube. To follow the disposition of this part of the septum clearly, it is to be noted that the thick mass into which the liver bud is growing is crescentic in shape, with the convexity ventralwards and the concavity dorsalwards, the arrangement being somewhat in the form of a collar round the floor and sides of the entodermal tube. The two cornua of the crescentic mass have embedded within them the vessels which are

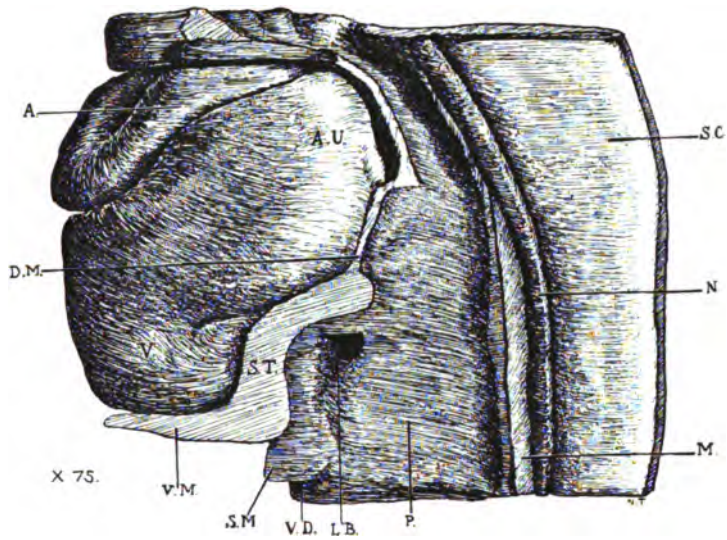


FIG. 1.—Part of model of embryo, with heart *in situ*. ×75.

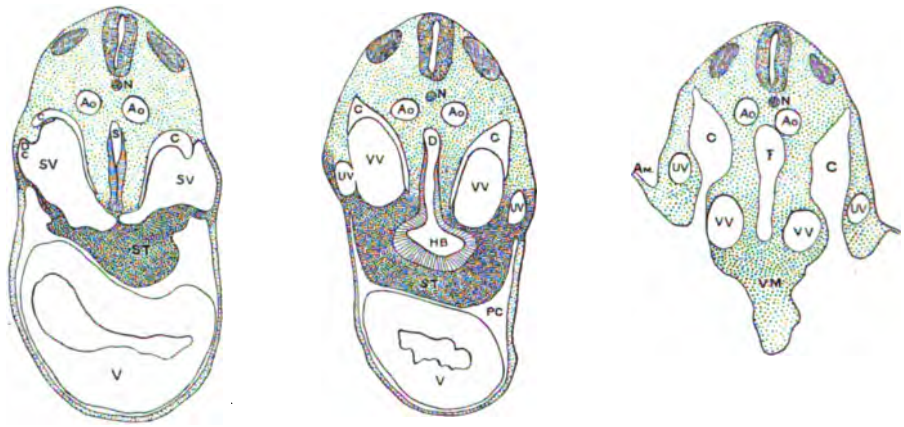
S.C., spinal cord; N., notocord; M., mesoderm between the two dorsal aortæ; A., aortic stem; A.U., auricle; D.M., dorsal mesocardium; S.T., septum transversum; V.M., ventral mesentery; S.M., wall of vitelline duct; V.D., cavity of vitelline duct lined by entoderm; P., duodenum; L.B., liver bud.

passing along the lateral aspect of the alimentary canal to the venous end of the heart, viz.—the umbilical and vitelline veins on each side, as well as a part of each horn of the sinus venosus. Both the crescentic mass and its cornua are continuous laterally with the body wall.

It is interesting to notice here that this third constituent of the septum transversum is the first part to be formed. It is laid down before the reversal of the pericardial area, at the anterior end of the embryonic rim, as a thickening of mesoderm, which soon unites with the extra-embryonic mesoderm, so that when the reversal of the pericardial area has been accomplished, it occupies a position in front of the umbilicus. It is continuous, on the one hand, with the somatic and splanchnic layers of the

pericardial mesoderm, and on the other with the mesoderm of the amnion and the yolk sac. In it the vitelline veins run to reach the venous end of the heart, and subsequently the ducts of Cuvier and the umbilical veins, when the lateral mesocardia are formed and when the more caudal part of the septum has enlarged and united with the lateral body wall.

The obliquely placed mesodermal septum becomes greatly influenced by the outgrowth of the hepatic bud. There is a marked increase of the septum at this point, and, as the model shows, there is now a thick cushion hollowed for the reception of the liver. It is this thickening, together with the parts forming the bed for the vessels passing to the sinus venosus,



A. B. C.

FIG. 2.—Schematic representation of three sections of embryo. A, at level of sinus venosus; B, at level of liver bud; C, at level of ventral mesentery.

N., notochord; Ao., aorta; S.V., sinus venosus; S.T., septum transversum; C., cœlom; D.C., ductus Cuv.; V., ventricle; P.C., pericardial cavity; S., stomach; H.B., liver bud; V.V., vitelline vein; U.V., umbilical vein; Am., amnion; V.M., ventral mesentery; I., small intestine.

which His (1) described under the name of septum transversum or primary diaphragm.

From a consideration of its mode of formation it seems convenient, however, to describe the mesodermal septum, as seen in an embryo at the beginning of the third week, as consisting of the following parts: (1) the part forming the bed for the passage of vessels to the sinus venosus; (2) the thick hepatic part associated with the development of the liver; and (3) the ventral mesentery. The "pulmonary ridge" (F. P. Mall, 8), out of which the pleuro-pericardial and the pleuro-peritoneal membranes are formed, which Mall regards as an extension of the septum transversum, is not yet differentiated.

The relations of the oblique septum to the cœlom are well known, but it may here be pointed out that whereas the septum is first laid down anterior to the cavity of the pericardium, after the reversal of the pericardial area it lies behind it, forming the floor of the pericardium, and later, as in the present specimen, dorso-posterior to it. The cœlomic cavity on either side is indeed flexed round the dorsal and anterior free edge of the septum, so that the single pericardial cavity is below and in front and the trunk cavity above and behind. Uniting these are the two narrow passages of the cœlom, known as the dorsal parietal recesses of His and Ravn. Each recess communicates with the pericardial cavity by the pleuro-pericardial opening, and with the abdominal cœlom by the pleuro-peritoneal opening. These recesses form the beginnings of the pleural cavities, towards which, even at this early stage, the already paired lung buds are seen to be growing. It will be clear that the caudal boundary of each parietal recess is formed by the cornu of the transverse septum.

It is interesting to find that the arrangement of the mesoblastic septum in the human embryo is very similar to what has been described in some other mammals. Professor Robinson (7), in a paper on the development of the lungs of rats and mice, points out that "the opening of the fore-gut into the umbilical sac is placed immediately behind the heart, and is separated from the latter organ by a layer of mesoblast formed by the union of the splanchnic and somatic layers, which meet at this place. From this point of union a mesoblastic septum extends forward and dorsally to the anterior end of the body cavity, which it divides into a ventro-anterior portion, the pericardium, and a dorso-posterior portion, the pleuro-peritoneal cavity. The septum contains the vitelline veins and the ducts of Cuvier, and gives origin eventually to the walls of the pericardial sac and ventral half of the central portion of the diaphragm." Professor Robinson's description of the mesoblastic septum thus refers to the stage after complete separation of pericardium from pleura, later, therefore, than that described above in the human embryo; and he believed at the time that there were lateral infoldings in the pericardial area, which he has more recently shown us is not correct, as far as mammals are concerned.

Ravn (2) distinguishes in the chick four constituent parts of the whole septum transversum: (1) the middle mass into which the liver grows; (2) the two lateral mesocardia; (3) the unpaired median primary ventral ligament of the liver; and (4) the two lateral closing folds of the septum transversum. These latter folds extend inwards from the body wall to the septum transversum, between the lateral mesocardia and the primary ventral ligament of the liver, and are concerned in the closure

of the "ventral parietal recesses," which are present in birds in addition to the "dorsal parietal recesses."

The Liver Anlage.

Fig. 3 represents drawings of a model of the liver bud and part of the entodermal tube, from the left side and from the front. The bud grows out from the alimentary tube opposite the third and fourth cervical somites as a median structure with thick walls enclosing a cavity in wide communication with the alimentary canal. Its relations with the septum transversum are seen in fig. 1. When seen from the front, it would appear that the greater part of the outgrowth is to the left of the middle line.

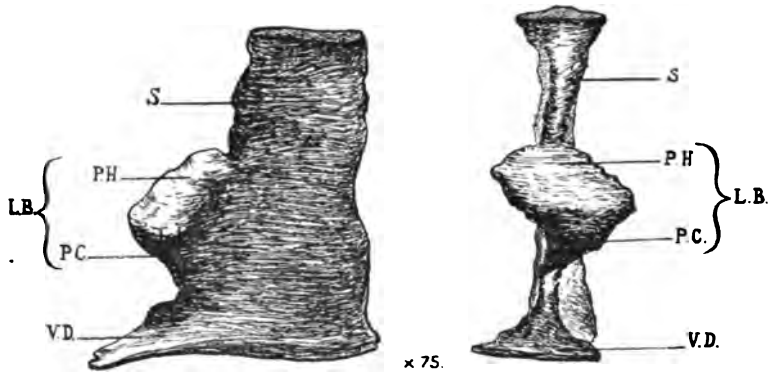


Fig. 3.—Model of entodermal tube showing the hepatic bud. × 75. Seen from the left side and the front.

S., stomach; L.B., liver bud; P.H., pars hepatica; P.C., pars cystica; V.D., vitelline duct.

The gall-bladder has not yet formed, and there is no sign of the dorsal or ventral pancreas.

The liver bud exhibits an extremely early phase of development. It may be divided into two parts, cephalic and caudal, the "pars hepatica" and the "pars cystica" of Maurer. In most mammals, according to F. Maurer (10), it is possible to distinguish the cranial division of the anlage from the caudal. The former gives rise to the group of liver cells, and the latter to the gall-bladder. An interesting model showing the further differentiation of the liver bud and its relation to the ventral pancreas in a human embryo of 4·9 mm. has been recently described and figured by Dr Ingalls (11). He finds that the two parts of the ventral pancreatic anlage arise, one on the right side, the larger of the two, and one on the left, as outgrowths between the pars hepatica and the gut, and that they unite caudally to the pars cystica. A little later there is only one

ventral pancreas anlage, and it is uncertain, according to Dr Ingalls, how much the left side contributes to it.

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THE BRAINS OF ABORIGINAL NATIVES OF AUSTRALIA IN THE ANATOMY SCHOOL, CAMBRIDGE UNIVERSITY.

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PART II.

4. The Frontal Region.

Sulcus precentralis inferior (S. arcuatus):

(1) The relation of this sulcus to the Sylvian fissure has been discussed in the preceding paragraph (3). In the present place, the connexion of the superior and inferior precentral sulci will be considered first. These sulci are confluent in 62·5 per cent. of the Australian hemispheres, as compared with 9·3 per cent. of European hemispheres (Cunningham).

In respect of this greater frequency, the Australian brain does not resemble that of the human fœtus, in which the occurrence is rare (though I have the brain of an infant, fourteen days old, in which this confluence is present). Nor can it be shown that such confluence is characteristic of the brains either of the Simiidæ or lowlier members of the order Primates.

The subsequent observations lend themselves, more readily than those which precede, to the numerical method of setting forth the results of the examination of the several brains. Accordingly the remaining data in this section will be discussed in relation to Table II., in Section 3 of which these statistics will be found. The percentage figures refer in all instances to hemispheres, not to brains.

Sulcus precentralis inferior (S. arcuatus)—*continued*:

(2) Confluence of this sulcus with the sulcus frontalis inferior is observed in 62·5 per cent. of hemispheres. There is a slightly greater tendency for this junction to be effected in the left hemisphere than in the right. The figures published by Karplus [1] corroborate this statement, and the combined data provide a percentage of frequency amounting to 60. Comparison with the percentages recorded by Retzius and Cunningham respectively (for Swedish and British brains) show that very large fluctuations in this character appear to obtain. On the whole, the Australian brain

[1] *Über ein Australier-gehirn*, Obersteiner's Arbeiten, 1902, Heft ix.

is most like that of the human fœtus shortly before birth, and least like the brains of the Simiidæ.

(3) In respect of the position of the arcuate sulcus as defined by the so-called fronto-precentral index, reference to the table (Table II., part 2, and also the analysis) shows that the Australian brain bears a curious resemblance in this character to the brain of the

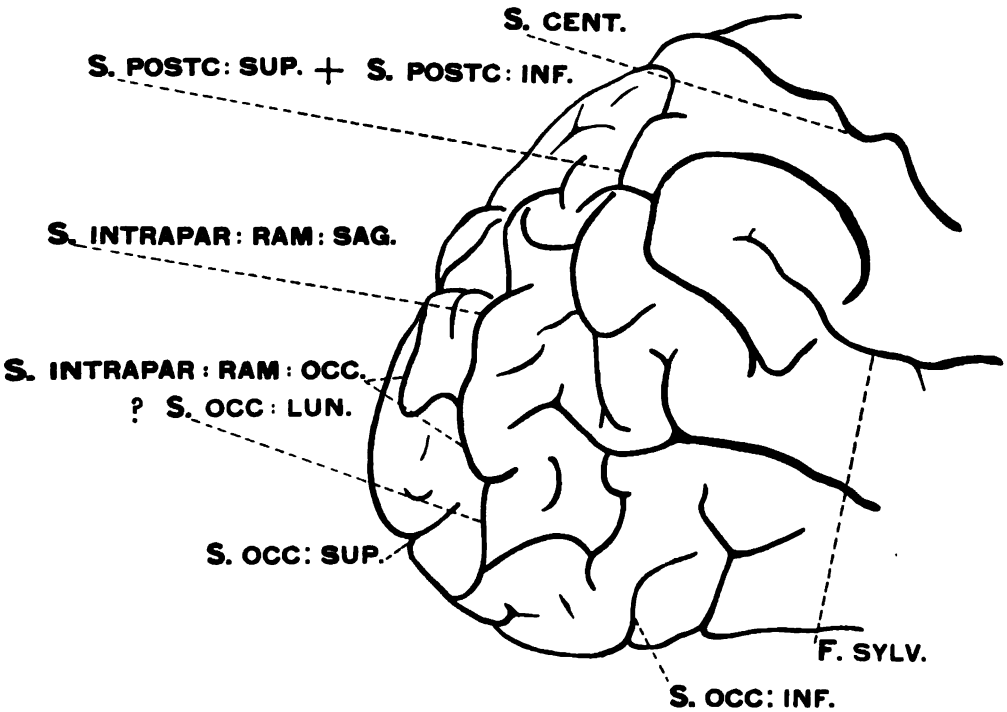


FIG. 9.—Australian brain No. 2. Right hemisphere. Occipital lobe.[1]

European fœtus at the fifth month. There is some difference between the right and left hemispheres, to the latter of which the foregoing statement particularly refers.

(4) In no instance was the confluence of the sulcus precentralis inferior with the sulcus transversus inferior recognised. But such confluence is characteristic neither of the brain of the human fœtus nor of those of the Simiidæ.

[1] Since these hemispheres were represented in my *Text-Book of Morphology and Anthropology* in 1904, I have been able to study them much more closely than was previously possible, and to correct some errors of detail. The figures published herewith provide the most accurate representations (at my command) of the actual conditions.

(4*a*) Sulcus radiatus of Eberstaller.—This sulcus has an independent existence (*i.e.* apart from the sulcus frontalis inferior) in 50 per cent. of the Australian brains at Cambridge, or, if the data provided by Karplus' specimen be combined with the preceding, the percentage of occurrence is 60. This figure is nearer that

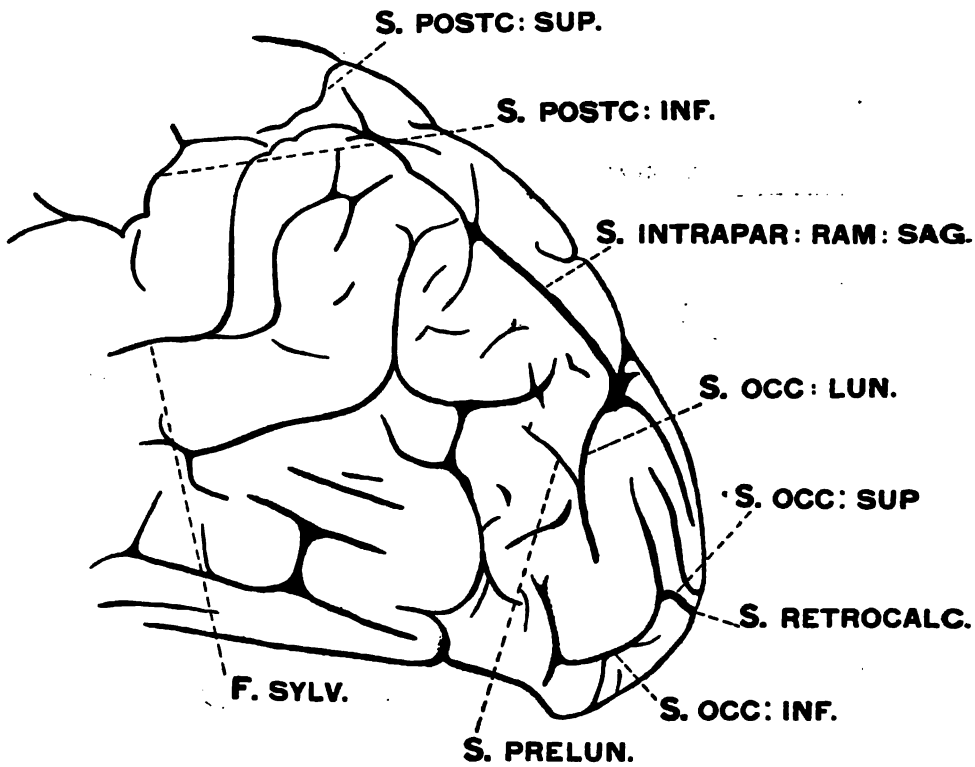


FIG. 10.—Australian brain No. 2. Left hemisphere. Occipital lobe.

To the abbreviations noted under fig. 1, Part I., the following should now be added:—
S. prelun. Sulcus prelunatus. *Op.* Opercular fold.

provided by European fœtuses than that furnished by adult brains, and cannot be regarded (*cf.* Table II.) as a simian character.

Sulcus precentralis marginalis.—This is present and independent in half the hemispheres (50 per cent). Cunningham states that it is very frequent in the collection of brains examined by him. In a collection (used for purposes of control) of sixteen hemispheres of fœtuses of the latest stages and two hemispheres of an infant

fourteen days old, I recognised the sulcus in 35·3 per cent., but it did not occur in any hemisphere of the Simiidæ examined by me. I do not find any difference between the two halves of the brain in respect of the occurrence of this sulcus.

Sulcus precentralis medius.—This has an independent existence in one hemisphere (12·5 per cent). Cunningham describes it as "inconstant" in European (Irish) brains. There is some reason to regard the independence of this sulcus as a simian characteristic, since out of ten hemispheres of Simiidæ I found three in which there was a distinct and isolated sulcus in the position indicated by the name. Cunningham (Cu. vii., p. 292) figures such a sulcus in the brain of a chimpanzee, but states (p. 293) that "it is difficult to decide whether the furrow . . . is the lower piece of this sulcus (viz. S. precentralis superior) or a sulcus precentralis medius." As I have already mentioned, when I noticed a sulcus in the appropriate position in the hemisphere (whether of an Australian aboriginal or of an anthropoid ape), I have called it sulcus precentralis medius.

Sulcus precentralis superior.—This sulcus joins the sulcus frontalis superior in seven hemispheres out of the eight (87·5 per cent.). Eberstaller (quoted by Cunningham) describes this as an absolutely constant connexion. Cunningham, however, recognises exceptions to this general statement. The exceptions (as regards British brains) appear to me to be somewhat numerous in fœtal brains, for in my series of the latter the percentage of confluence is only 41·2.

There is no very great difference between the human brain and that of the Simiidæ in this respect.

Sulcus frontalis medius.—This sulcus, the arrangement of which is said by Cunningham to be "very variable," is found in six out of eight Australian hemispheres (seven out of ten if Karplus' figures are added) to consist of a single furrow, distinct from that known as Wernicke's fronto-marginal sulcus. In one instance the S. frontalis medius is in two segments, to which Wernicke's sulcus is accessory.

The predominant arrangement (75 per cent. or 70 per cent.) cannot be accurately compared with that obtaining in European hemispheres. As already noted, Cunningham describes the arrangement in Irish brains as being variable. For Swedish brains, Retzius seems to describe an arrangement comparable to that which has just been termed the predominant one in Australian hemispheres. Retzius gives 24 as the percentage of occurrence in the hemispheres examined by him.

The series of fœtal European brains, as well as the simian brains examined by me, provide data which show that the prevalent arrangement in these is one in which the several elements of the sulcus frontalis medius are continuous with each other and with Wernicke's sulcus; in other words, so far as these

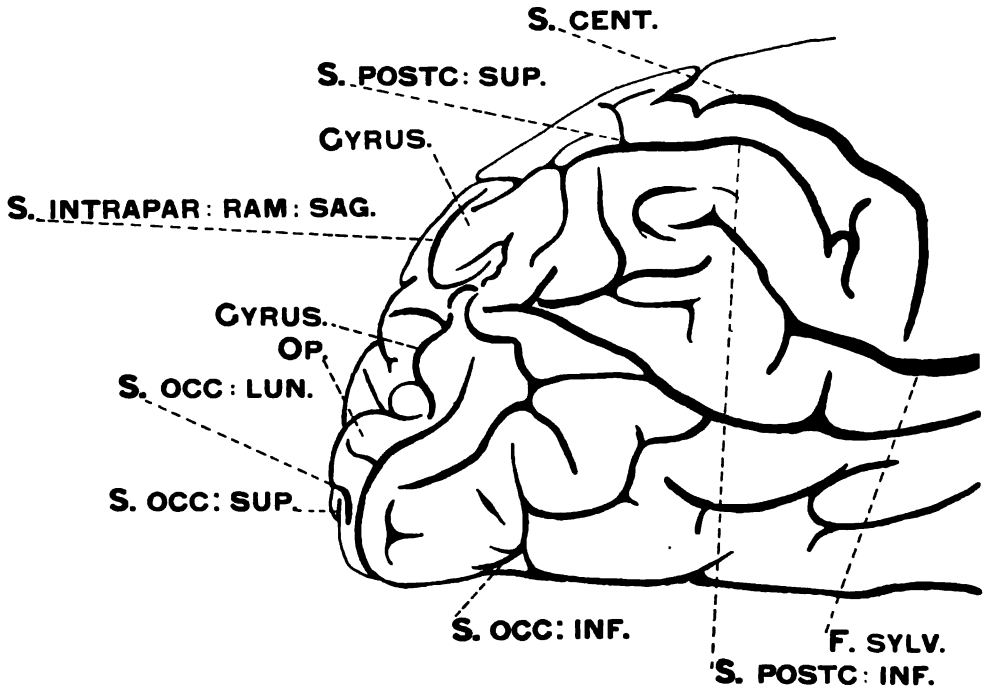


FIG. 11.—Australian brain No. 3. Right hemisphere. Occipital lobe.

observations go, the Australian hemisphere stands apart, and is distinct from those of Western Europeans, whether adult or fœtal, and also from those of the Simiidæ.

Sulcus fronto-marginalis of Wernicke.[1]—Two terminal portions, in

[1] It is perhaps worthy of remark that Cunningham and Elliot Smith do not seem to be in accord regarding the morphological relations of this sulcus. Thus Cunningham (*Cunningham Memoir*, No. vii., pp. 266, 267) clearly regards Wernicke's sulcus as the frontal continuation of the sulcus frontalis medius, a sulcus of late appearance in the Primate series. On the other hand, Elliot Smith (*Catalogue R.C.S.*, pp. 444, 452) evidently considers that Wernicke's sulcus is part of the sulcus frontalis inferior, a much older sulcus than the sulcus frontalis medius.

Lastly, it may be mentioned that Cunningham refers Eberstaller's and not Wernicke's fronto-marginal sulcus to an origin from the sulcus frontalis inferior.

continuity with a stem, and distinguished as the mesial and lateral branches respectively, are recognisable in 71·4 per cent. of Australian hemispheres. Retzius records 19 per cent. in Swedish brains. Cunningham quotes deviations from this mode

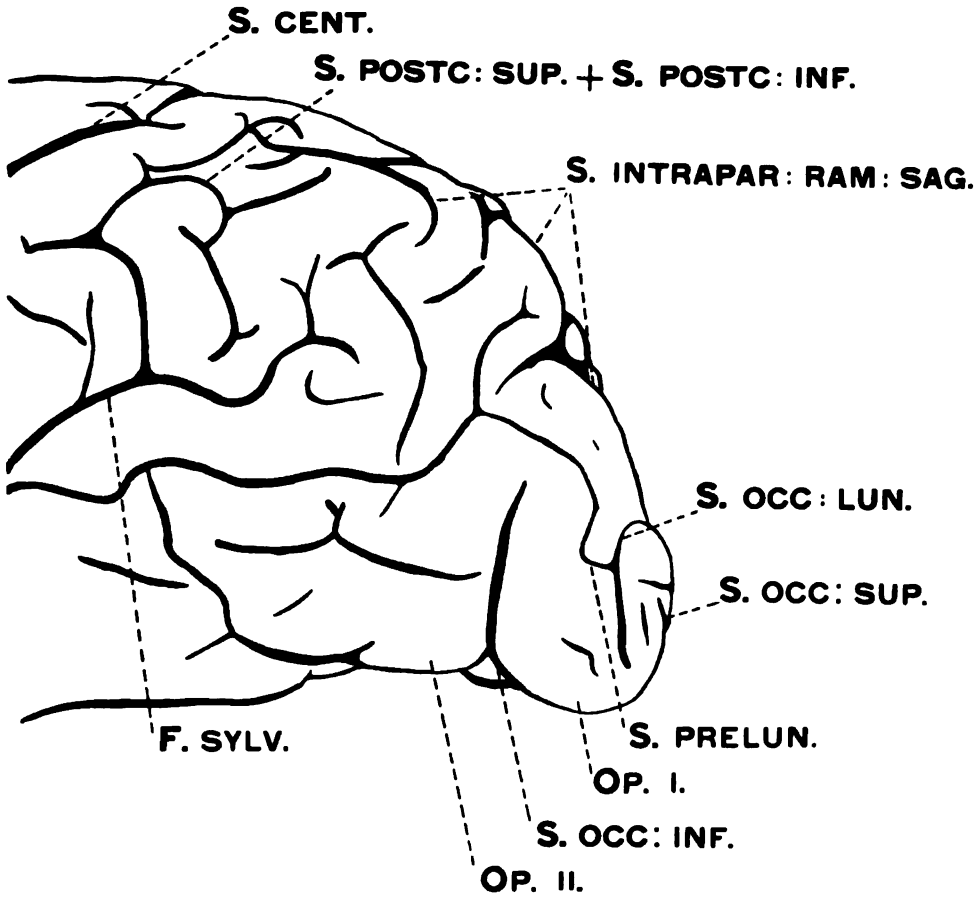


FIG. 12.—Australian brain No. 3. Left hemisphere. Occipital lobe.

in two ways, with frequencies amounting to 27·9 per cent., from which it may be inferred that in 72·1 per cent. of the brains examined by Cunningham the two branches occurred in continuity with the stem of the sulcus. The fact that of these two terminal branches the outer is the longer more frequently than is the inner in Australian hemispheres, may be held to support

Cunningham's view that the outer or lateral is developmentally the older, and the real continuation of the original sulcus. Eberstaller supports the claims of the mesial limb or branch. My observations on human fœtal brains do not support the statement of Cunningham. The Australian brains are not differentiated from those of British adults in respect of these characters.

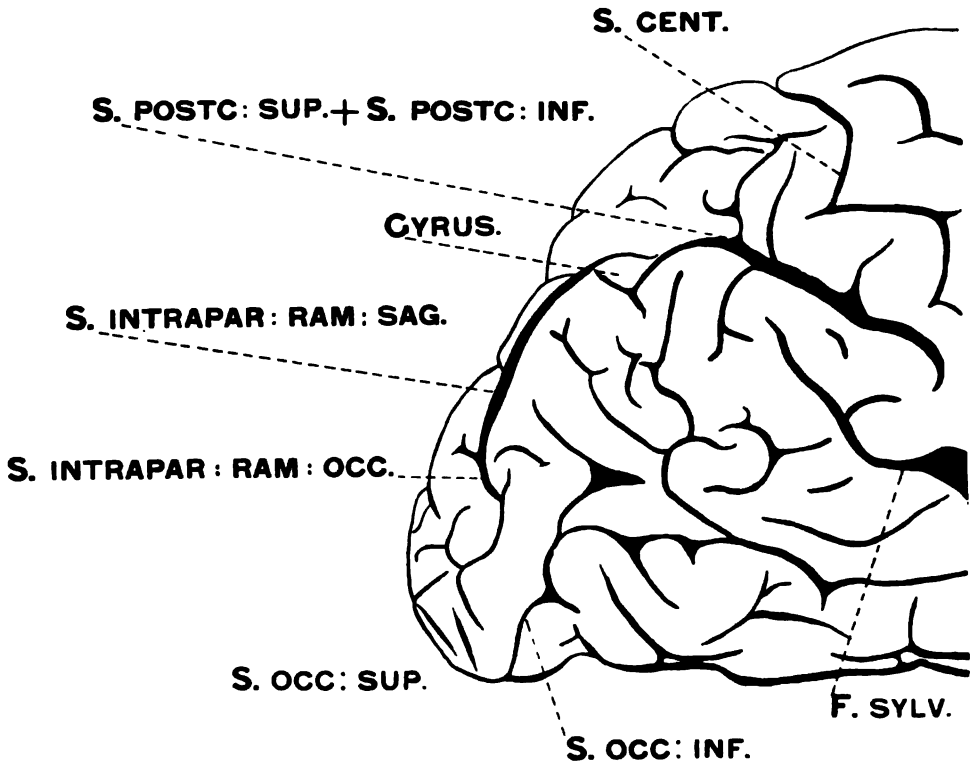


FIG. 13.—Australian brain No. 4. Right hemisphere. Occipital lobe.

Sulcus frontalis mesialis.[1]—This furrow is represented by a number of short sulci, all of which are free and disconnected from other sulci in seven out of the eight hemispheres of Australians, while in the remaining example one of these small furrows forms a connexion with the sulcus frontalis superior. In no case is there a continuous sulcus. There is thus no distinctive feature as regards

[1] This sulcus is thus designated in the *Cunningham Memoir*, No. vii. But in the second edition of Professor Cunningham's *Text-Book of Anatomy*, the term paramedialis is employed. See also the footnote in reference to the sulcus paramesialis of the occipital lobe.

this sulcus in the Australian brain. I may note that in the fœtal hemispheres of the eighth and ninth months the elementary grooves or furrows are by no means constantly present.

Sulci orbitales.—Inasmuch as these sulci are, in the majority (75 per cent.) of the Australian hemispheres, simple in appearance and devoid of minute branches, this character allies the Australian

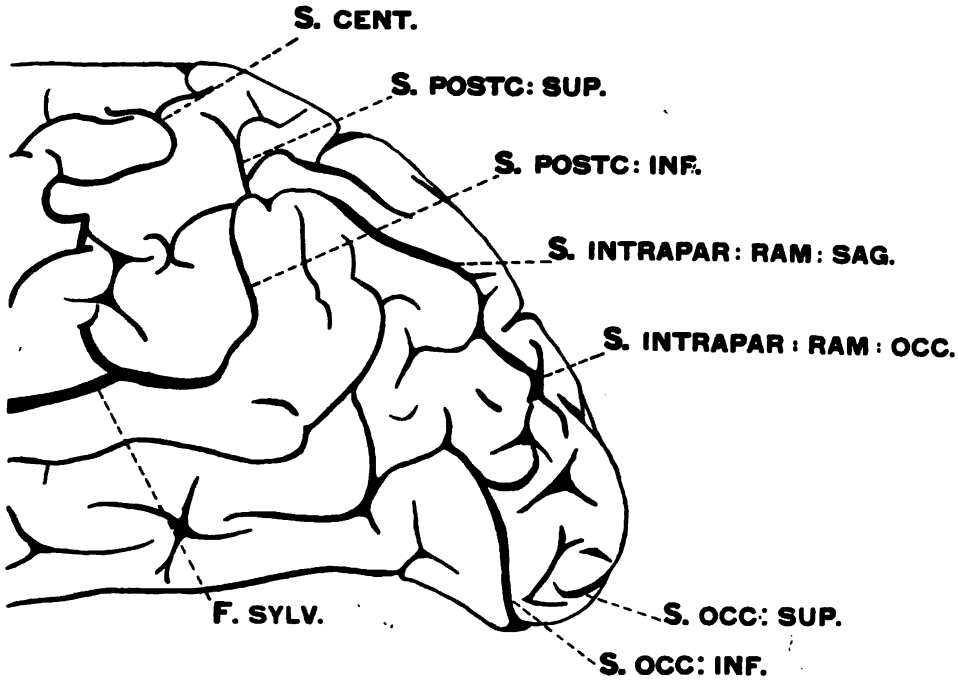


FIG. 14.—Australian brain No. 4. Left hemisphere. Occipital lobe.

brains to those of European fœtuses and those of Simiidæ. But I do not wish to lay stress on this, since the mode of observation is somewhat crude.

5. The Parietal Region.

The first character upon the list (in Section 1) is that of fulness of the parietal lobe. Owing to the long sojourn of the Australian brains in alcohol, so much distortion has occurred that accurate records are out of the question. Observations show that Nos. 1 and 4 are distinctly deficient in respect of parietal development, as compared with Nos. 2 and 3. In the

latter, the absolute mass of the parietal lobe is no doubt smaller than in the European brain, but otherwise (allowance being made for the state of preservation of the specimens) there does not seem a very distinct inferiority to European brains, when one considers the parietal development in relation to the development of the hemisphere as a whole.

Sulcus intraparietalis.—The analysis (for which *cf.* Table II.) of the

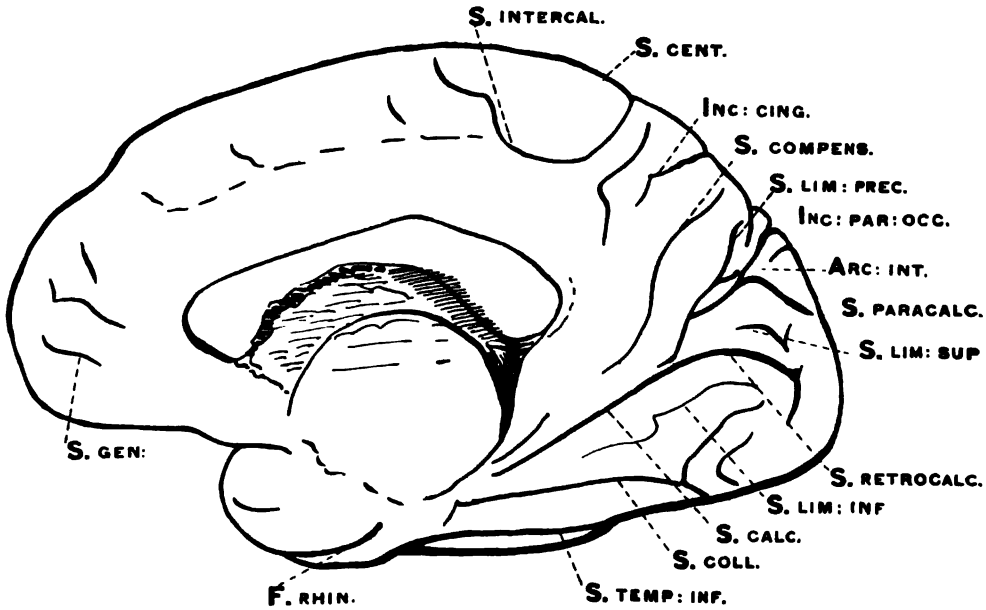


FIG. 15.—Australian brain No. 1. Right hemisphere. Mesial aspect.

The following abbreviations are used in this and the succeeding illustrations of the mesial aspects of the brain :—

S. intercal.	Sulcus intercalaris.
S. centr.	Sulcus centralis of Rolando.
Inc. cing.	Incisura cinguli.
S. compens.	Sulcus compensatorius.
S. lim. prec.	Sulcus limitans precunei.
Inc. par. occ.	Incisura parieto-occipitalis.
Arc. int.	Arcus intercuneatus.
S. paracalc.	Sulcus paracalcarinus.
S. lim. sup.	Sulcus limitans superior (areæ striatæ).
S. lim. inf.	Sulcus limitans inferior (areæ striatæ).
S. retrocalc.	Sulcus retrocalcarinus.
S. calc.	Sulcus calcarinus.
S. coll.	Sulcus collateralis.
S. temp. inf.	Sulcus temporalis inferior.
F. rhin.	Fissura rhinalis.
S. gen.	Sulcus genualis.
S. Seitz.	Sulcus of Seitz.
S. occ. sup.	Sulcus occipitalis superior.

observations on the mode of confluence of the several components of this sulcus shows in the first place that, judged by this test, the Australian brain resembles that of the negro of Africa (as described by Cunningham) rather than that of the European (Retzius and Cunningham); secondly, that the Australian brain, while differing from that of the European, agrees with the negro

brain in approaching the simian condition. But neither the Australian nor the negro brain approaches the simian brain quite so closely as does the human (European) fœtal brain from the eighth month to the time of birth.

On the whole, then, the agreement in conformation of the Australian brain is with that of the African negro. My data for fœtal brains differ slightly from those provided by Cunningham, but perhaps afford a juster comparison with my own observations upon the Australian brains. Thus I find the ramus occipitalis free from confluence with other elements of the sulcus intraparietalis in 47·2 per cent. as against 55 per cent. quoted by Cunningham. Lastly, the Australian hemispheres most frequently present the mode of conformation designated Type III. by Cunningham, and this statement, like the others made above regarding the intraparietal sulcus, holds good equally when the data provided by Karplus' specimen are combined with those of the Cambridge examples.

Arcus parieto-occipitalis.—The results of observations and measurements are summarised in Table I. part 3 (*q.v.*), and show that the Australian hemisphere herein resembles that of the European fœtus rather than the adult brain. But no marked simian affinity is herein recognisable in the Australian brain.

Relative length of the sagittal part of the sulcus intraparietalis.—This test reveals no simian character in the Australian brain (*cf.* the summary of observations in Table I., part 3). Nor can the Australian brain be said to stand nearer to the European fœtal brain than to the adult brains. It is noteworthy that, in respect of this character, the nearest approach to the Hominidæ is made not by the Simiidæ among the Primates, but by the Cebidæ (Cunningham).

6. The Occipital Region.

Sulcus retrocalcarinus.—This sulcus is continued (probably through amalgamation with the sulcus occipitalis superior) to the lateral aspect of the hemisphere in 37·5 per cent. of the Australian specimens. This figure is in close accord with the percentage (40) observed in the hemispheres of Simiidæ, while differing from that (16·6) noted in human fœtal hemispheres. Such extension of the retrocalcarine sulcus can thus be regarded definitely as a simian character. It remains to add that the character is here confined to the left hemisphere, and is in accord with the greater frequency of occurrence of the simian sulcus occipitalis lunatus on that side.

The retrocalcarine sulcus of the Australian brain is not so frequently bifid at its occipital end as in European brains. The Australian hemispheres provide a percentage of 50, whereas in a series of European hemispheres Bolton[1] found bifurcation in no less than 87·5 per cent.

In the former, the right hemisphere more often has a bifid sulcus, and the whole series is more simian than are European brains. In the Australian hemispheres no constant difference in length obtains between the two divergent limbs at the bifurcation. Bolton states that the average length of the upper branch is less than that of the lower. The Australian hemispheres agree with those of Simiidæ in this respect.

Sulci limitantes areæ striatæ.—Both of these are recognisable in 71·4 per cent. of examples (or 77·8 per cent. when Karplus' specimen is included). In the remaining 28·6 per cent. (or 21·2 per cent.) the lower sulcus alone was present. In no instance was the upper sulcus identified in the absence of the lower. On the whole, this test approximates the Australian brain to that of the European fœtus.

Sulcus occipitalis lunatus.—In two hemispheres (both of the left side) this sulcus is present in an absolutely typical form. In two other hemispheres, one right and one left, it can be recognised. In the remaining four hemispheres the sulcus is not identifiable. Combining these data with those provided by Karplus' specimen, it is found that this sulcus is recognisable in 60 per cent. of Australian hemispheres. In a series of human fœtal hemispheres I recognised the corresponding sulcus in 41·2 per cent. of examples, and, as is well known, the sulcus is constant in the brains of the Simiidæ. I do not know of any other tables of statistics indicative of the frequency with which the sulcus occurs in other human brains, but it is evidently frequent in those of Soudanese negroes (in which, indeed, its real nature was pointed out by Elliot Smith), and it occurs not uncommonly in the brains of adult Europeans. The greater frequency of its occurrence in the left hemisphere has been pointed out by Elliot Smith.

Sulcus occipitalis superior.—This sulcus occurs in each hemisphere: unlike its representative in the Simiidæ, it here not infrequently joins the retrocalcarine sulcus. This junction is more frequent in the left hemisphere. A variant of this arrangement occurs in the junction of this sulcus with that portion of the retrocalcarine which, when

[1] Cf. *Phil. Trans. Roy. Soc.*, series B, vol. cxciii., p. 171.

detached, has received the name of Seitz' sulcus. In neither of the foregoing features, nor in respect of its junction with the sulcus occipitalis inferior, does the present sulcus (occ. sup.) confer on the Australian hemisphere any particular resemblance to that of the Simiidæ, nor indeed in the last two respects does it present a fœtal mode of conformation. In the European fœtal brains examined by me the sulcus occipitalis superior joins the sulcus retrocalcarinus in 16·6 per cent. of hemispheres only.

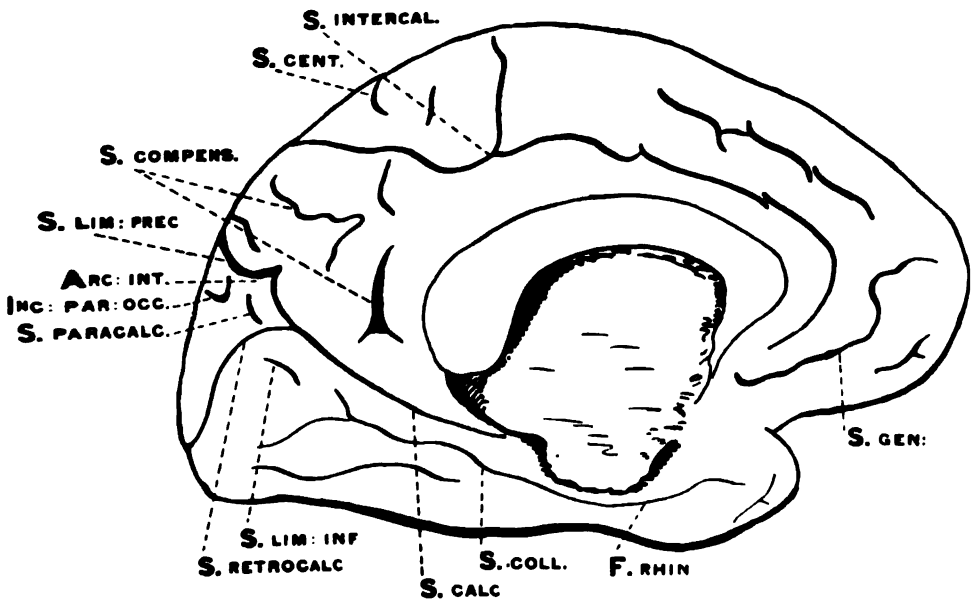


FIG. 16.—Australian brain No. 1. Left hemisphere. Mesial aspect.

For adult European brains I have so far no comparative statistics.

Sulcus occipitalis inferior.—This sulcus is constantly present, as in the brains of Simiidæ. In the series of fœtal European hemispheres the percentage was slightly lower, viz. 94 per cent. No particular inference can be drawn from the study of this sulcus, so far as it has been investigated here. It may be said that the Australian hemisphere in this respect resembles that of the ape and of the European fœtus. But it remains to be seen whether this character affords a means of distinguishing the Australian from the (adult) European brain. I am not inclined to anticipate this. In one

Australian brain the opercular character of the upper lip of the inferior occipital sulcus is distinctly pithecoid in each hemisphere.

Sulcus prelunatus.—The data collected with regard to this sulcus indicate that in this respect the Australian hemisphere differs from that of the European fœtus and at the same time tends to resemble that of the anthropoid ape. There is, however, some difficulty in dis-

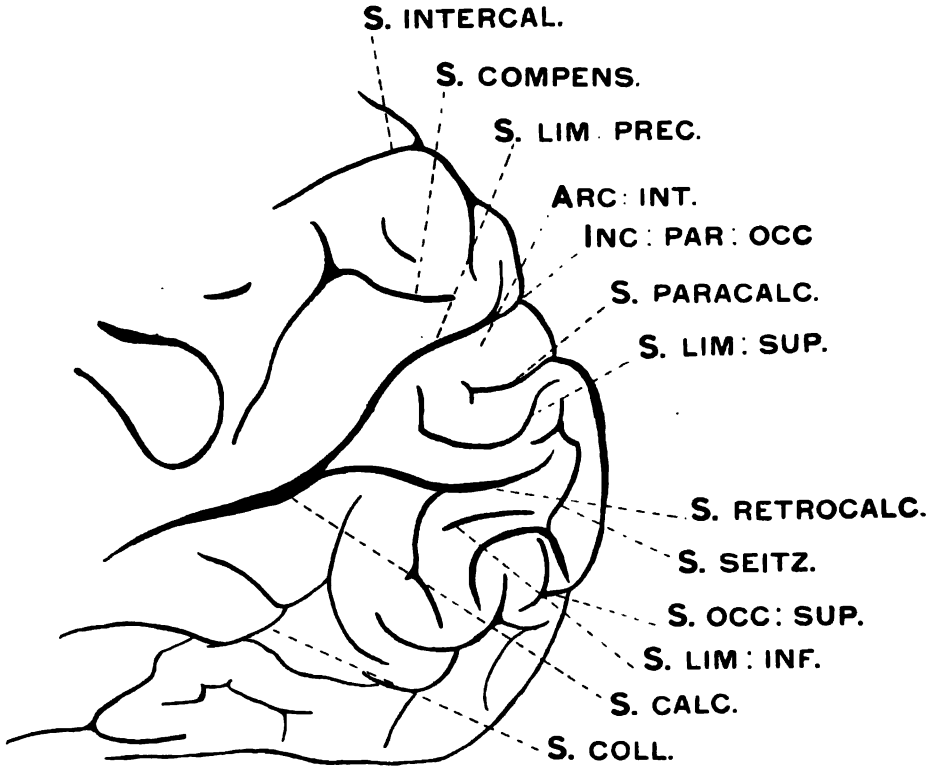


FIG. 17.—Australian brain No. 2. Right hemisphere. Mesial aspect.

tinguishing this sulcus, in the absence of the sulcus occipitalis lunatus.

Sulcus paramesialis.[1]—The frequency of occurrence of this sulcus is less than that of the preceding (S. prelunatus). In this respect the Australian hemisphere differs from those of European fœtuses and those of the Simiidæ alike.

Sulcus occipitalis transversus (the occipital component of the complete

[1] This sulcus is to be distinguished from the sulcus frontalis paramedialis.

intraparietal sulcus).—This sulcus extends to the sulcus lunatus in all instances in which the latter sulcus is present in the Australian hemispheres, or 50 per cent. of the Cambridge specimens: 60 per cent. if Karplus' specimen is added to these. This figure approximates the Australian hemisphere to that of the Simiidæ rather than to that of the European fœtus.

The sulci paracalcarinus and limitans precunei, with the incisura parieto-occipitalis, are constantly present, as in all brains of the Simiidæ, and in many European fœtal brains. The general disposition of these sulci in the Australian Brain No. 4 (fig. 22) is particularly simian, resembling the arrangement often seen in brains of gorillas (as represented in fig. 19 of Elliot Smith's monograph, E.S.Gov., 1904) and in some brains of Soudanese negroes. The occurrence of such marked simian affinity in one brain out of this small collection is indicative of the lowly status of the Australian aboriginal in respect of cerebral conformation.

Gyrus cunei.—This was detected in each hemisphere which admitted of examination (100 per cent.). In the brains of anthropoid apes it seems to be constantly present, but in fœtal human hemispheres I did not find it in more than 66·6 per cent. of examples. The Australian hemisphere is in this respect to be regarded as simian rather than fœtal. On the other hand, this gyrus is in no case exposed in the Australian hemispheres. In Irish brains such exposure does not quite reach a frequency of 4 per cent. (Cunningham), but in my series of fœtal hemispheres the percentage was 20, and in simian hemispheres exposure was complete or partial in 70 per cent. of specimens. Cunningham (Cu. vii., p. 41) states that such exposure is constant in brains of the Chimpanzee, less frequent in those of Simia and Hylobates.

Annectant gyri in the sulcus retrocalcarinus.—Of the two gyri commonly described, the posterior is much the more frequent; moreover, it is exposed on the surface, and more or less interrupts the retrocalcarine sulcus in 85·7 per cent. of instances. On the other hand, the records of the frequency of the anterior annectant gyrus are imperfect, owing to the difficulty of observation and the poor state of preservation of the specimens (especially of Brain No. 1).

Taking these annectant gyri and the gyrus cunei together, we find that the most frequent Australian type of conformation resembles those named by Cunningham (*Cunningham Memoir*,

vii. p. 38, fig. 15) Types II. and IV., and herein is an indication that the affinities of the Australian brain are with those of

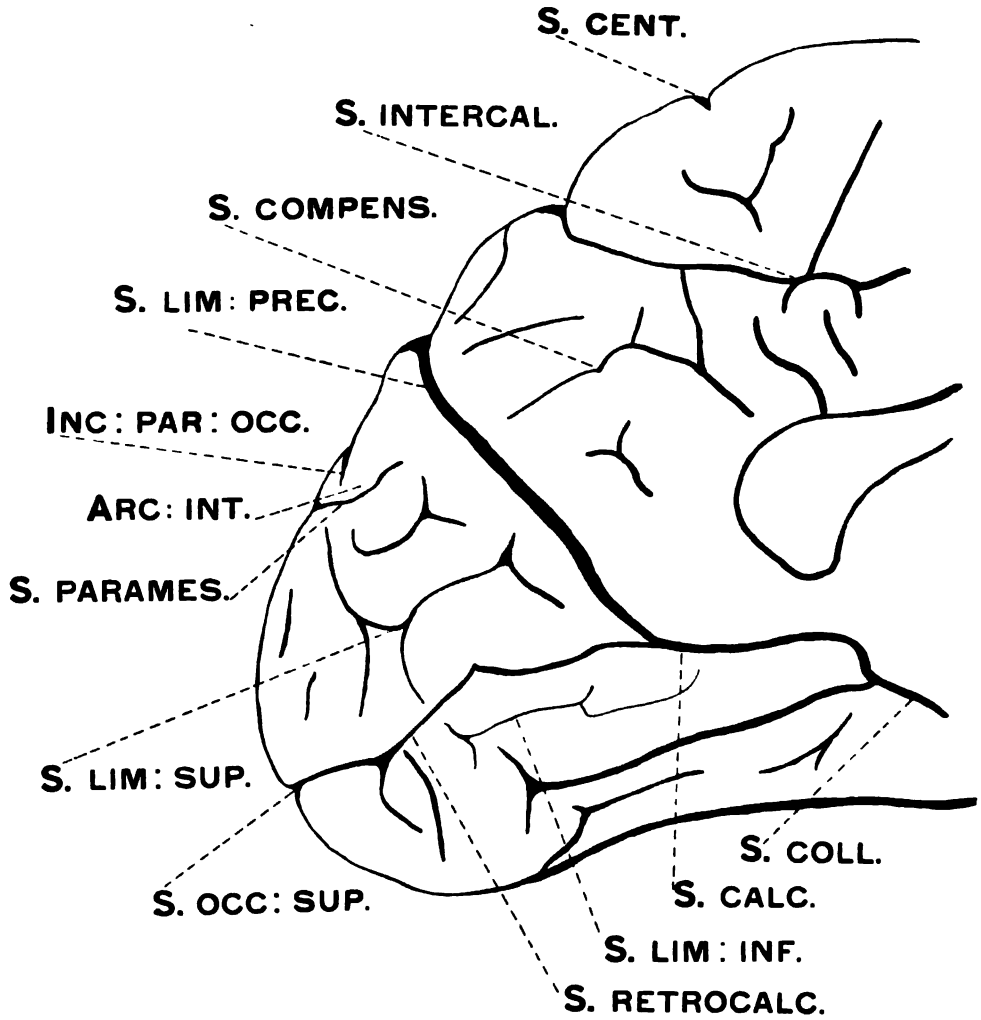


FIG. 18.—Australian brain No. 2. Left hemisphere. Mesial aspect.

negroes and European fœtuses rather than those of adult Europeans.

Arcus intercuneatus.—This is recognisable in all cases. As it is fully exposed in 42·8 per cent. of examples, while the corresponding

frequencies are 18·6 per cent. for the European fœtus and 33·3 per cent. for Simiidæ, simian resemblances are hereby denoted. Brain No. 3 in particular provides an excellent demonstration (in the left hemisphere) of the primitive position of this convolution, viz. on the lateral and not on the mesial aspect of the hemisphere.

7. The Temporal Region.

Sulcus temporalis primus (parallel sulcus). — This sulcus is usually bent sharply upwards at its hinder end, as in the Simiidæ, and also in the cynocephalous monkeys. The same character is shown by the records in Table II. to be frequent in the brain of the European fœtus. No very important inference can be drawn from this feature. The junction of the parallel sulcus with the intraparietal sulcus occurs in Australian brains about as often as in those of European fœtuses and in those of anthropoid apes, in none of which is the confluence a common one. As regards confluence of the parallel sulcus with the sulcus prelunatus, the Australian hemisphere exhibits a faint resemblance to those of the Simiidæ. Again, in respect of the number of portions of which the adult sulcus is composed, it is found that, as might be expected, the fœtal hemispheres show frequently (31·3 per cent.) two of the small components of the continuous sulcus of the adult. The Australian hemisphere does not closely resemble the fœtal European hemisphere herein, but is quite like that of the adult European, to judge by Retzius's statistics for the brains of Swedes. European and Australian brains alike differ from those of anthropoid apes.

Sulcus temporalis secundus.—The observations made on this sulcus relate to the number of its component parts. In this respect the sulcus in the Australian brain resembles that of the European fœtal brain, while differing from the brains of the Simiidæ. In the latter the tendency is for simplicity, *i.e.* fusion of the components, which remain distinct in the human brains. The foregoing remarks refer to the combined series of Australian brains at Cambridge, together with Karplus' specimen.

Sulcus temporalis tertius.—This is recognisable in all the Australian hemispheres, as in all those of the Simiidæ (and also of Cercopithecidæ). The other characters of this sulcus, of which records were obtained, are: the opercular character of its upper margin, and the number of its component parts. In both these respects

the Australian hemisphere resembles those of European fœtuses rather than those of the Simiidæ. Comparative data for adult European brains were not accessible.

Gyrus temporalis primus.—In one Australian hemisphere (*cf.* fig. 6) this

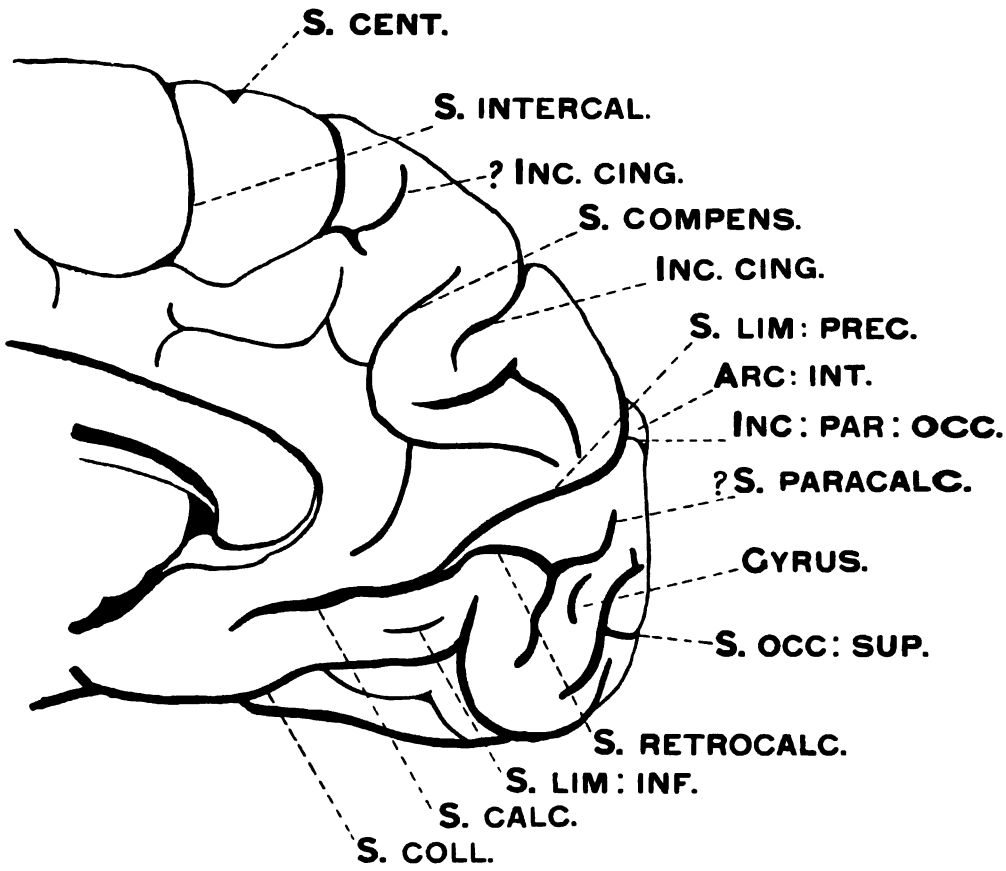


FIG. 19.—Australian brain No. 3. Right hemisphere. Mesial aspect.

gyrus is very strongly constricted near the mid-point of its length. A comparable constriction, though in no other case so marked, was detected in 40 per cent. of the combined series of Australian hemispheres. There seems no difference between the right and left hemispheres in this respect.

This conformation is not simian, nor, so far as I am aware, is it characteristic of adult European brains. So far as my observa-

tions go, there is some tendency to the production of the anomaly in European fœtal brains (represented by a percentage-frequency in hemispheres of 26·5).

Sulcus collateralis.—In a large majority of the Australian hemispheres

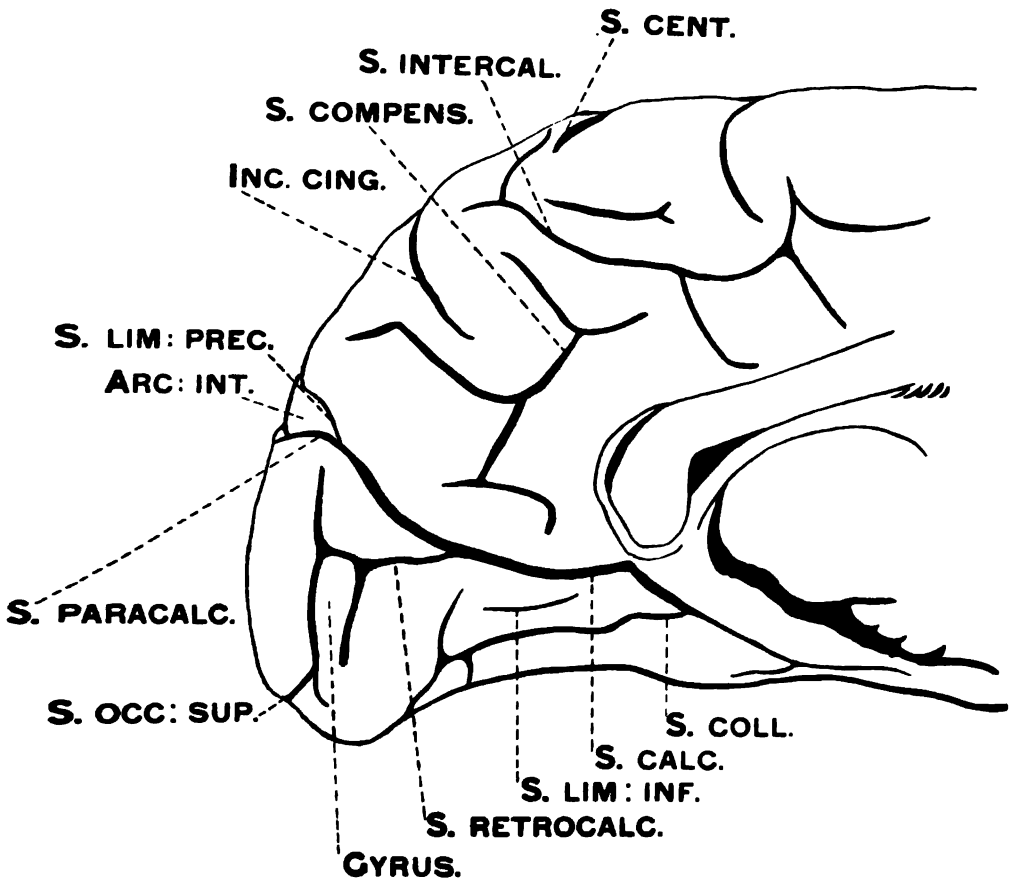


FIG. 20.—Australian brain No. 3. Left hemisphere. Mesial aspect.

(90 per cent. of the combined series) this sulcus has a bifurcated posterior extremity. Herein it resembles the corresponding sulcus in the Simiidæ more than that of the European fœtus. In one instance the sulcus is in two parts, and in another the form of bifurcation assumed is that of the letter T.

The collateral sulcus in the Australian hemispheres does not often join the calcarine (or the retrocalcarine) sulcus; but it is

frequently seen to be confluent with some part or representative of the fissura rhinalis. These appearances do not admit of any exact inferences: as regards confluence with the calcarine sulcus, the Australian brain differs alike from those of European fœtuses

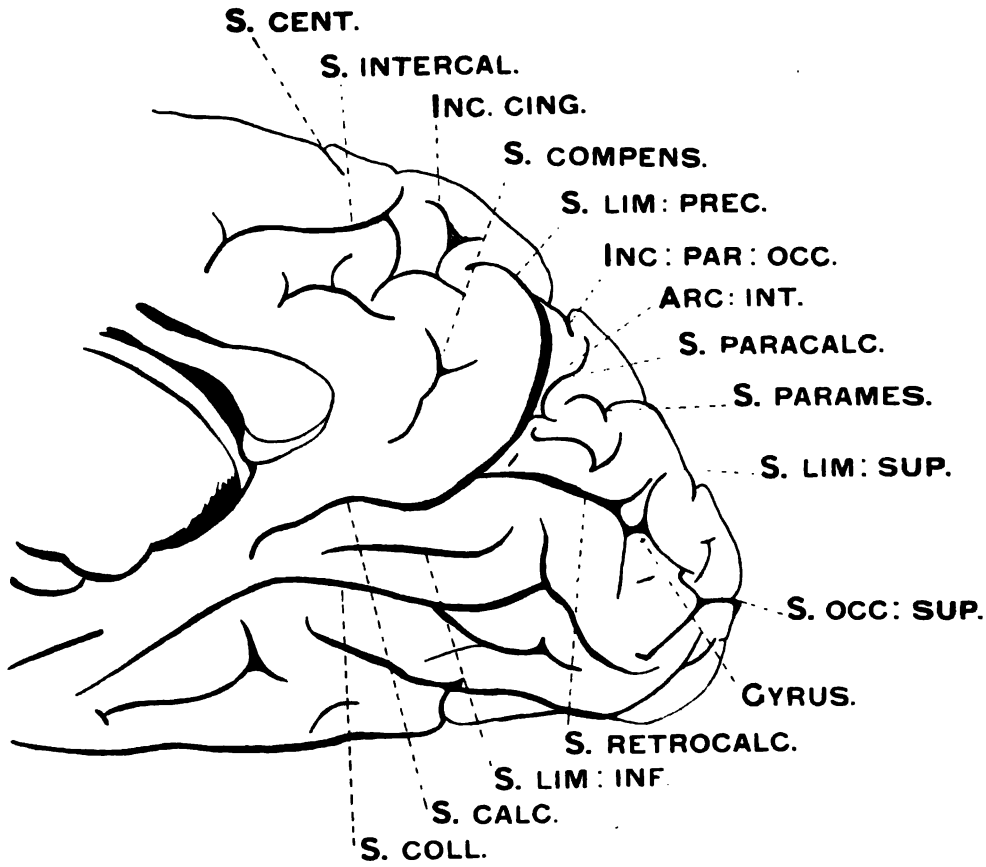


FIG. 21.—Australian brain No. 4. Right hemisphere. Mesial aspect.

and the Simiidæ. With reference to confluence with some portion of the fissura rhinalis, the frequency in Australian hemispheres far exceeds that observed in European fœtal hemispheres, while this confluence does not seem to occur at all in simian brains.

Temporal lobe.—The extent to which the pole of this lobe projects beyond the uncus cannot be determined with accuracy. It does

not appear to be less prominent than in the hemispheres of adult Europeans, so that no diagnostic value can be attached to this character in the present connection. The lesser degree of projection in the simian brain has been rightly dwelt upon by Cunningham as a distinctive character of the anthropoid apes.

8. The Mesial Aspect of the Hemisphere.

Sulcus intercalaris.—(*a*) In respect of the number of component parts of this sulcus, the Cambridge specimens of Australian hemispheres seem to form a group apart from adult European brains (Retzius), fœtal European brains, and brains of Simiidæ. The distinctive feature is the tendency to a large number of sulci persisting throughout life. But the small number of specimens somewhat discounts the value of this conclusion.

(*b*) Union of the intercalary sulcus (or one of its parts) and the incisura cinguli is observed in 37·5 per cent. of hemispheres, and herein resemblance is to be found to the European fœtal brain.

(*c*) Confluence of the intercalary sulcus (or one of its components) with the compensatory sulcus is observed in 12·5 of hemispheres. Herein again the resemblance is to the European fœtal brain rather than to that of the Simiidæ.

(*d*) The intercalary sulcus ends immediately behind the median end of the central sulcus in 50 per cent. of cases (60 per cent. if Karplus' specimen is included). Herein a tendency to the simian condition is to be observed.

(*e*) The very distinct branch given off by the intercalary sulcus immediately in front of the termination of the central sulcus in every case, seems to me to constitute a simian feature. This branch was met with in 40 per cent. of simian hemispheres, but in 28·6 per cent. only of European fœtal hemispheres.

Sulcus compensatorius.—This sulcus was observed in all cases. No distinction is here possible between the Australian and other human brains. Most commonly the sulcus is composed of a primary portion, to which a secondary part is accessory in half the hemispheres (50 per cent.). This constitutes a difference from European fœtal hemispheres, as well as from those of Simiidæ, in which the sulcus is commonly single. In one Australian hemisphere as many as four fissurets are to be seen.

Incisura cinguli.—(*a*) This is recognisable in five out of eight Australian hemispheres at Cambridge (62·5 per cent.), and the percentage of frequency is 50 if Karplus' specimen is combined

with these. This sulcus cannot be identified in the hemispheres of Simiidæ at my disposal. The percentage of occurrence in the

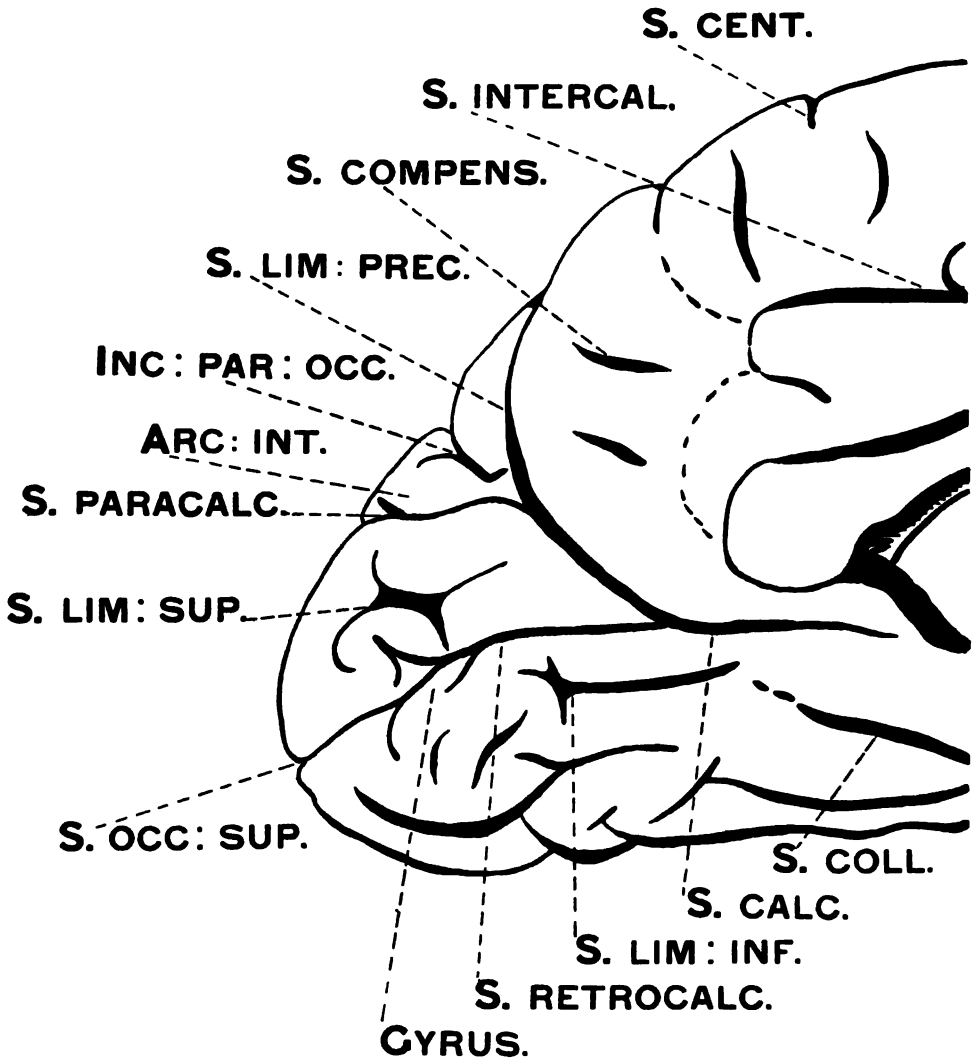


FIG. 22.—Australian brain No. 4. Left hemisphere. Mesial aspect.

series of fœtal hemispheres surpasses that of the Australian hemispheres, for it amounts to 87·5.

(*b*) The frequency of confluence of the incisura cinguli with all, or

part, of the sulcus intercalaris is the subject of comment in connexion with that sulcus (*v. ante*).

Genual and rostral sulci.—These are seen in all the hemispheres, as in those of Europeans (whether adult or fœtal) and of the Simiidæ. The Australian hemispheres are distinguished from those of European fœtuses (which resemble herein those of the Simiidæ) by a tendency to the union of the rostral sulcus (not the genual sulcus) with the anterior extremity of the sulcus intercalaris. The simplicity of the folding of this part of the cortex in the Australian brain is a primitive feature, which, however, is shared by those of European fœtuses and of the Simiidæ alike.

STUDIES IN THE ANATOMY OF THE PELVIS, WITH SPECIAL REFERENCE TO THE FASCIÆ AND VISCERAL SUPPORTS.

By G. ELLIOT SMITH, M.A., M.D., Ch.M., F.R.S., *Professor of Anatomy, Cairo.*

PART I.

THIS is an attempt to describe the fasciæ of the pelvis and the mechanical means of support of its viscera, as I have observed them in twenty adult subjects and a series of fœtuses and children, specially dissected for this purpose. I began this investigation with no other idea than the desire to see for myself the structures which Mr Douglas Derry had demonstrated in an admirable series of dissections (1), and of testing the adaptability of the views advocated by him to the needs of students. But in the course of this work I have observed so many new or neglected facts, which in the main confirm and extend Derry's researches, that I have decided to add my contribution to his.

Even in schools of anatomy where subjects of European extraction are dissected, every conscientious demonstrator must have realised the difficulty of harmonising the facts observed in the actual body with the description of the pelvic fascia which the student usually finds in his text-book. Even if he soon learns that the skilful use of the scalpel enables him to present an arrangement of structures which agrees fairly well with the account given in his manual of dissection, I do not suppose that he would have given any such description of what he sees unless it had become the traditional and stereotyped way of doing so.

But those of us who have to teach anatomy from subjects of negro origin or of negro admixture, frequently find that the discrepancy between the disposition of parts in the body dissected and the conventional description of them is so great and so patent, that no skill with the knife will delude even the dullest student into the belief that his text-book gives a correct account of the structures he sees.

Before Mr Douglas Derry left Edinburgh to come to Cairo, he had begun the investigation of the pelvic subperitoneal tissues in Professor Cunningham's department. The rich supply of material which he has found in Egypt, often exhibiting conditions which the European anatomist would regard as bizarre, has naturally given a wider scope to his studies;

and the results of his work, which were presented to the meeting of the Anatomical Society of Great Britain and Ireland in Edinburgh (July 1907), form an important contribution to the elucidation of this much-discussed region of the body.

While I was preparing my manuscript for the press, and after all (except two) of my drawings were finished, that magnificent encyclopædia of pelvic anatomy—Delbet's, Pasteau's, and Rieffel's contributions to the second edition of Poirier and Charpy's treatise (2, 3 and 4)—came to hand. So much that I had intended putting into this communication has been so thoroughly described and analysed by Delbet and Rieffel, that I have been able in many instances to substitute references to their work in place of long discussions. Ever since the time of Denonvilliers (15), the accounts of the pelvic fascia given by French writers have deviated widely from those found in German and English books, and I do not think that anyone who critically examines this literature, and compares it with what he finds in the dissecting-room, can refuse to admit the much closer approximation to accuracy in the French descriptions. The extraordinary neglect of such an obvious and important structure as the prostato-peritoneal aponeurosis of Denonvilliers, on the part of almost everyone except French anatomists, is only one of a large number of instances one might quote. One of the chief merits of Derry's work is the recognition of the rôle played by the mesodermal sheaths of the pelvic blood vessels and viscera; this is a subject that receives great attention in the treatises of Delbet (2, pp. 91–95) and Rieffel (4, pp. 465–473).

Although I have examined the structures here described in both sexes, I shall deal mainly with the condition in the male in the present communication. Most of the subjects discussed here are common to the two sexes, and those that are not have received far more attention hitherto in the female than in the male, because gynæcologists have for a long time attached great importance to the subperitoneal and perivascular tissues in the pelvis. In the course of the following account I shall briefly indicate from time to time—chiefly by reference to Rieffel's treatise (4)—the differences in the female sex.

This drawing (fig. 1) represents the semilunar fold of white fibrous tissue formed from mesodermal tissue condensed around the internal pudic artery, veins, and nerve, constituting a sheath—Alcock's canal—for these structures. Derry (1) has called this semilunar band the "*fascia* lunata." It is not correct to describe Alcock's canal as formed by "the splitting of the obturator fascia." It consists of an investment of fibrous tissue which has nothing to do with the sheath of the obturator internus muscle, and is attached to the neighbouring bony and ligamentous structures quite independently of it. It often happens (in the case of the human pelvis)

that the fascia lunata becomes attached to the surface of the sheath of the obturator internus (see figs. 3 and 4), but this does not always happen.

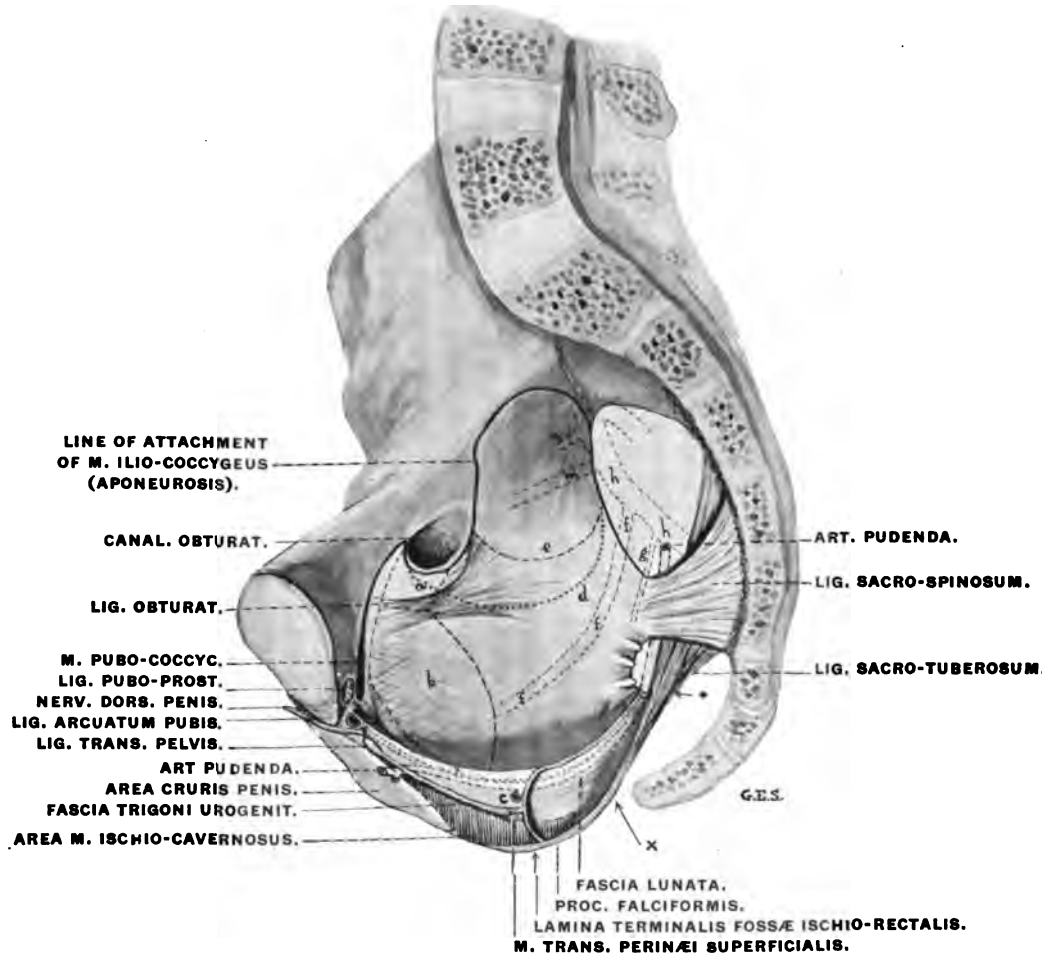


FIG. 1.—The right half of the pelvis of an Egyptian Fellah, from which the viscera and all the soft parts have been removed, with the exception of certain ligamentous structures, the internal pudic artery (ART. PUDENDA), and part of the dorsal nerve of the penis.

h, internal iliac artery; *n*, obliterated hypogastric artery; *m*, obturator artery; *f*, inferior vesical artery; *g*, middle hæmorrhoidal artery; *c*, artery to the bulb; *a*, upper thin part of the obturator membrane (*b*); LIG. OBTURAT., a strong band from which some fibres of the obturator internus muscle arise; X, the place where the section represented in fig. 4 was made.

The relations of the fascia lunata present considerable differences in the rectal (where it is called Alcock's canal) and urogenital triangles. In the

former it is an important element in the constitution of the lateral wall of the ischio-rectal fossa (see figs. 3 and 4); and when I come to the discussion of the boundaries of that important space, it will be seen that the fascia lunata completely shuts out the aponeurosis of the obturator muscle from any share in the formation of its walls, because it (the semilunar fascia) is attached to the skeleton by its inferior margin (fig. 4) and to the anal fascia (fig. 4, A) by its upper margin. In fact, the upper edge of the fascia lunata is joined to the inner surface of the anal fascia by means of a delicate band of fibrous tissue, the cut edge of which is shown in fig. 1 (in a somewhat diagrammatic fashion) along the posterior half of the

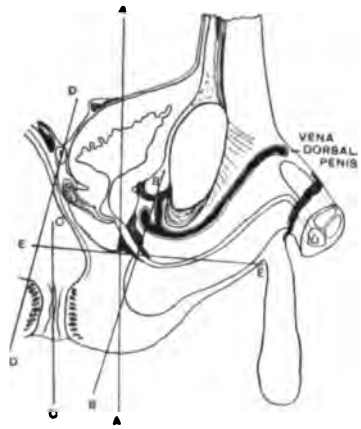


FIG. 2.—Part of the mesial sagittal section through the anterior part of the pelvis of a Soudanese negro, with five lines showing the planes in which the sections represented in figs. 3, 4, 5, 6, and 8 were made.

fascia. At the base of the triangular ligament the attachment of this limiting membrane (fig. 1, LAMINA TERMINALIS FOSSÆ ISCHIO-RECTALIS) leaves the upper margin and passes vertically downward across the surface of the fascia lunata just behind the artery to the bulb (*c*), the base of the triangular ligament (FASCIA TRIGONI UROGENIT.), and the superficial transverse perineal muscle.[1]

If it be recalled that the ischio-rectal fossa extends upward as far as the lower border of the lesser sciatic ligament (LIG. SACROSPINOSUM), this drawing will give a good idea of its precise extent in the sagittal plane.

[1] It is attached to the surface of the erector penis muscle, which extends into the outer wall of the ischio-rectal fossa. Whether or not this is a peculiarity of African subjects, in whom the penis is exceptionally large, I am unable to say; but I constantly find the origin of this muscle to be much more extensive than it is represented to be in books and memoirs dealing with European subjects.

Figs. 3 and 4 show its appearance when cut in the coronal plane, the lamina terminalis being marked with an asterisk (*) in the former, and with the letter A in the latter.

Although it is only a thin membrane, this structure, which I have called the *lamina terminalis fossæ ischio-rectalis*, is a very definite and

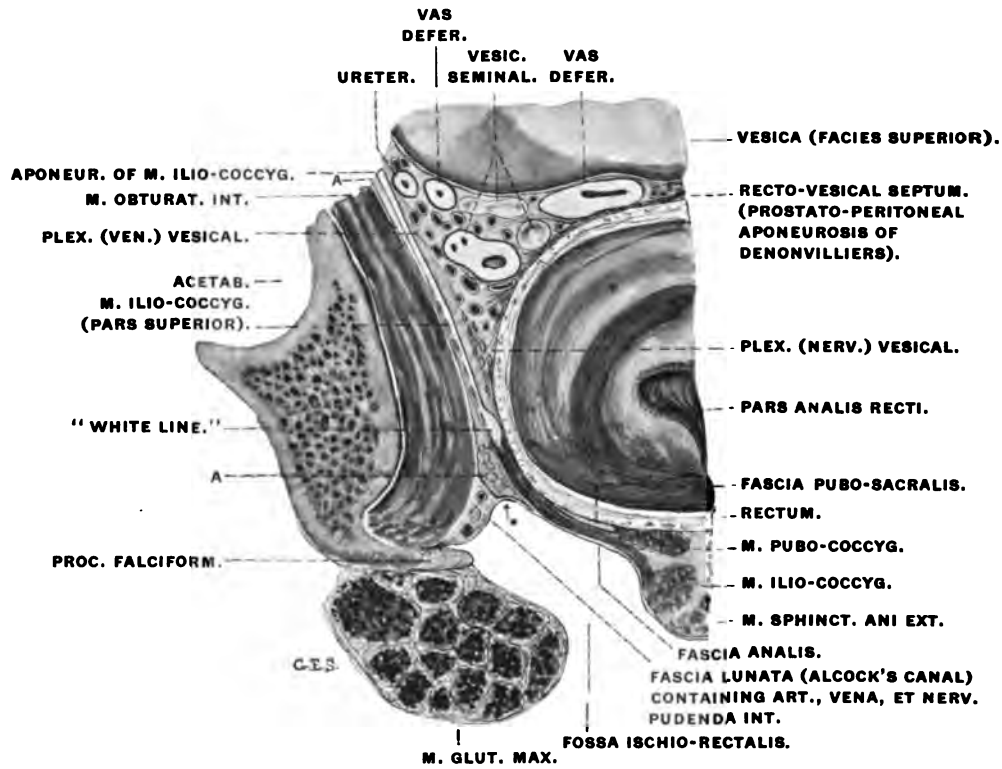


FIG. 3.—The left half of a section passing through the pelvis immediately behind the bladder and anal canal in the plane DD (fig. 2).

A is the supra-tegmental space—a cleft between the ilio-coccygeus (and its aponeurosis) and the obturator internus: it is filled with fat, separated from the ischio-rectal fossa by the lamina terminalis fossæ ischio-rectalis (*).

important element in the ischio-rectal wall. It is very strange that it seems to have been quite overlooked until Derry called attention to it. Surgeons have frequently remarked that when an ischio-rectal abscess bursts into the rectum, the opening is "nearly always within half an inch of the anus" (Treves), although the fossa is said to be "between 2 and 3 inches deep" (Treves). Although anatomists have overlooked this limiting membrane, the artists who have drawn illustrations for several treatises (for example,

those of Deaver (8), plate xiii., facing p. 30; and Holl (7), fig. 14, p. 215) have seen it and drawn it quite accurately; nevertheless the writers of these same books have constructed the conventionally inaccurate diagrams (8, plate xvi.; 7, fig. 1).

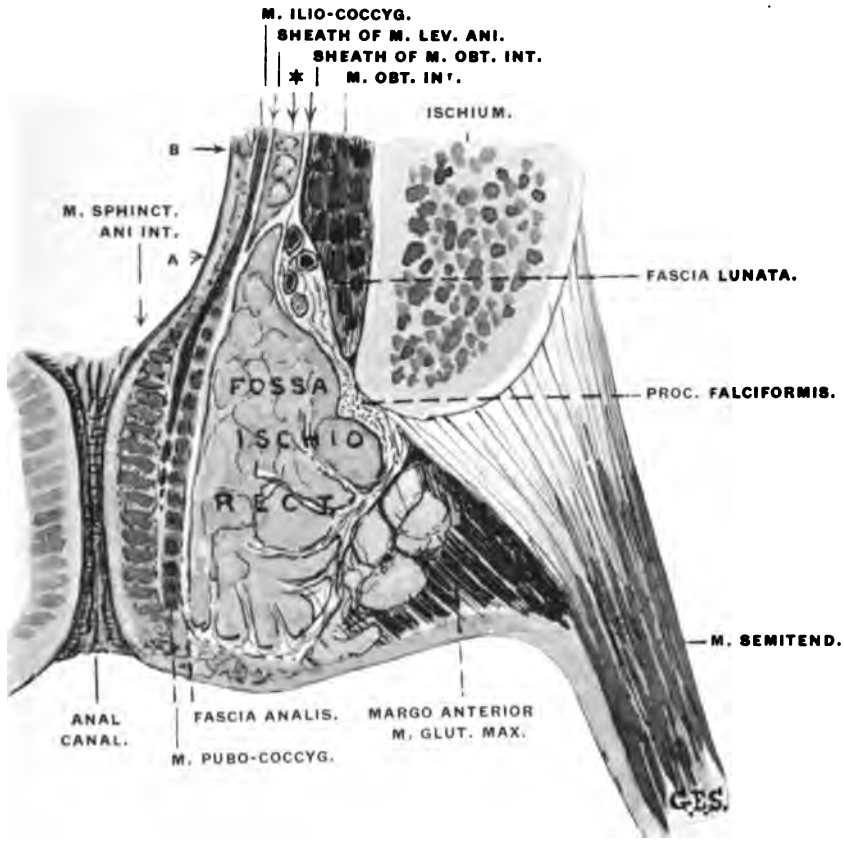


FIG. 4.—A section through the left ischio-rectal fossa (seen from the front) in the axis of the anal canal (fig. 2, C C).

This roof-membrane of the ischio-rectal fossa separates the latter space from a narrow cleft between the levator ani muscle (fig. 3, M. ILIO-COCCYG.) and the obturator internus. This cleft (fig. 3, A), which we might call the "supra-tegmental space," is filled with loose flocculent fat, and it is commonly regarded as the upper part of the ischio-rectal fossa, reaching up to the "white line" or beyond it. The failure to recognise this fact has led to the erroneous belief that the ischio-rectal fossa extends forward above

the base of the triangular ligament: but this is not so. It is limited in front by the membrane represented in fig. 1 (LAMINA TERMINALIS). The so-called anterior end of the ischio-rectal fossa—(see especially Delbet (2, fig. 107, p. 162), who has modified a figure taken from Spalteholz (9, fig. 677, p. 613) so as to show this so-called ischio-rectal fossa, which is not in the original)—is a prolongation of the supra-tegmental space (fig. 3, A) and not of the ischio-rectal fossa.

The term "Alcock's canal" is usually restricted to that part of the fascia lunata which forms part of the wall of the ischio-rectal fossa. In front of this the "canal" is commonly supposed to end when the internal pudic vessels "pass between the two layers of the triangular ligament," as the conventional description of the text-books represents it.

But the fascia lunata does not stop at the base of the triangular ligament. It traverses the whole length of the urogenital triangle; and, so far from becoming any weaker, it actually becomes stronger, because it affords an attachment to many fibres of the triangular ligament (figs. 5 and 6, FASCIA TRIGONI UROGENITALIS). For the condition found in the female, see the excellent picture drawn by Farabeuf, and borrowed by Rieffel (4, p. 677), to which I shall have occasion to refer again, and of the deep transverse perineal muscle[1] and the sphincter of the membranous urethra (figs. 6 and 7, M. SPHINCTER UROGENITALIS).

As in the posterior part of its extent, so also in the urogenital triangle, the fascia lunata forms a sheath for the internal pudic artery, veins, and nerve; but, before the anterior extremity of the fascia is reached (in fact, before the triangular ligament ends by joining the ligamentum transversum pelvis), the internal pudic artery emerges from its sheath on the anterior aspect of the triangular ligament (fig. 1, ART. PUDENDA); or, to describe it in the more usual manner, the artery perforates the triangular ligament. It is common to find the dorsal nerve of the penis described as also perforating the fascia trigoni, but in none of the subjects that I have dissected did this happen. In every case I have found it following the

[1] For the purpose of studying the deep perineal muscles, I excised the whole mass of tissue occupying the subpubic angle from the root of the penis to the prostate; this I cut in a series of sections parallel to the plane of the anterior aspect of the triangular ligament. From these sections I reconstructed the muscles and adjoining structures, and found an arrangement such as Kalischer (quoted by Eberth, fig. 174, p. 194) and Delbet (2, figs. 136 and 136 *bis*, pp. 212 and 213, and fig. 137, p. 214) have represented with great precision. The muscle described in text-books as the "compressor urethrae" consists of two independent muscles: the transversus perinæi profundus and the sphincter urogenitalis. The former arises from the surface of the fascia lunata and is inserted into the perineal body—centrum tendineum perinæi. The superficial (anterior) fibres of the urethral sphincter pass from the ligamentum transversum pelvis to the centrum on each side of the urethra, without any lateral attachment; but some of the deeper (posterior) fibres (figs. 6 and 8, and Delbet's fig. 136 *bis*) arise on each side from the inner surface of the fascia lunata.

course represented by Spalteholz (9) and Delbet (2); that is, it remains within its sheath of fascia lunata until it reaches a point just above the ligamentum transversum (fig. 1); then it emerges and passes obliquely upward and forward (in contact with the pubes) between the transverse and subpubic (LIG. ARCUATUM PUBIS) ligaments.

Contrary to the statements found in most text-books of anatomy, the dorsal vein of the penis (in most of my specimens) closely followed the

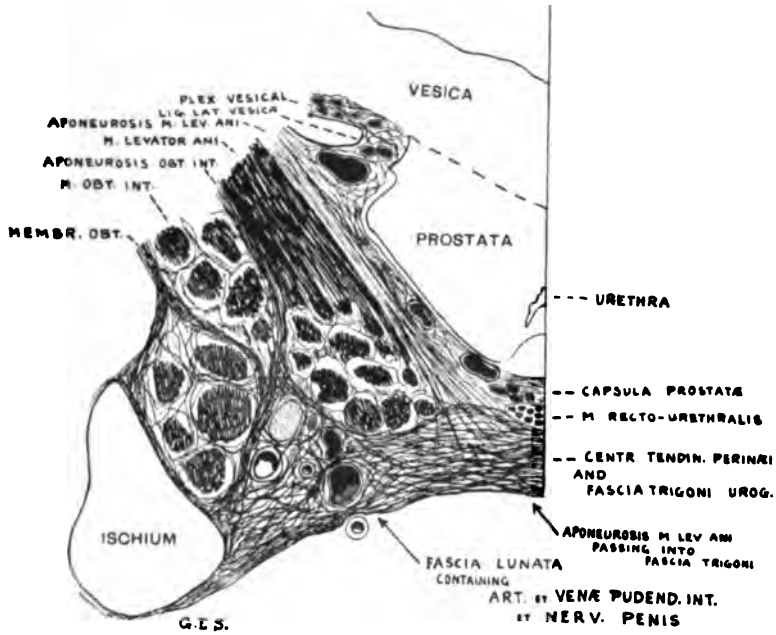


FIG. 5.—A coronal section through the left half of the prostate, base of the triangular ligament, and neighbouring structures in the plane A A (fig. 2).

This section was made in the specimen represented in fig. 2.

course of the dorsal nerve, and poured its blood into the large internal pudic veins. So near is the juxtaposition of these structures, that if the dorsal vein be excised from above (within the pelvis), the dorsal nerve will usually be found actually lying on it (fig. 7).

Many treatises (especially those written by British and American writers) not only neglect to describe this connection between the dorsal vein and one or both internal pudic veins, but even go so far as to deny its existence. I am aware of the fact that several text-books (for example, Quain's, Cleland and Mackay's, and Morris's) refer to "a slender branch of

communication" (to quote Cleland and Mackay) between the dorsal vein and the internal pudic; but that is a very different thing to the condition represented in figs. 6 and 7, where the large internal pudic vein of the left side is the direct continuation of the dorsal vein.

The attitude of British anatomists in regard to this matter is all the more surprising when it is remembered that, from the time of Henle

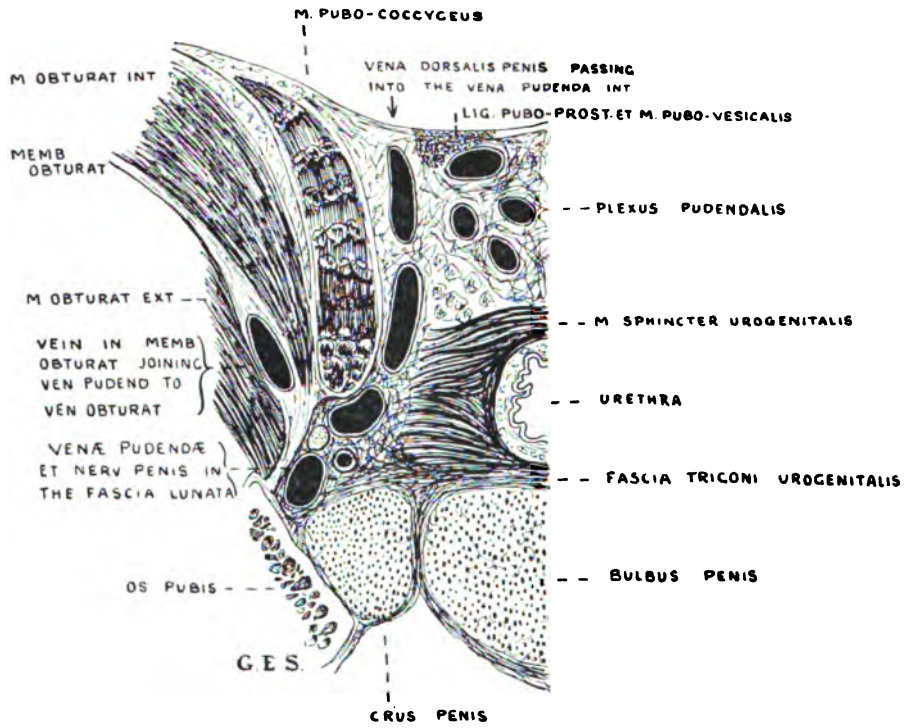


FIG. 6.—The left half of a section across the pelvis, immediately in front of the prostate (fig. 2, B B).

A comparison of this figure and fig. 5 with Farabeuf's beautiful drawing, reproduced in Rieffel, 4, p. 677, will make clear the condition found in the female.

onward, there has been published a very large number of perfectly accurate representations in European subjects of the condition such as I have found in Egyptians—of the free communication of the dorsal vein of the penis (or clitoris) with one or both internal pudic veins. From one volume of Poirier and Charpy's treatise alone one can pick out a whole series of most beautiful illustrations in confirmation of this statement:—in Delbet's section (2) there are Farabeuf's excellent figure (fig. 90, p. 122) and pictures

copied from Henle's book (fig. 89, p. 121, and fig. 136 *bis*, p. 213); in Rieffel's contribution to the same volume (4) we find very instructive illustrations of this same fact taken from the works of Tschaussow (fig. 393, p. 612), Luschka (fig. 411, p. 665), Henle (fig. 412, p. 667), and Savage (fig. 408, p. 656); and in the chapter written by Glantenay there is Spalteholz's well-known figure (fig. 51, p. 66). Many more examples may be culled from the writings referred to in the bibliographical list, but those I have quoted are sufficient to show that this direct continuity of the dorsal vein of the penis and the internal pudic, the existence of which is either denied altogether

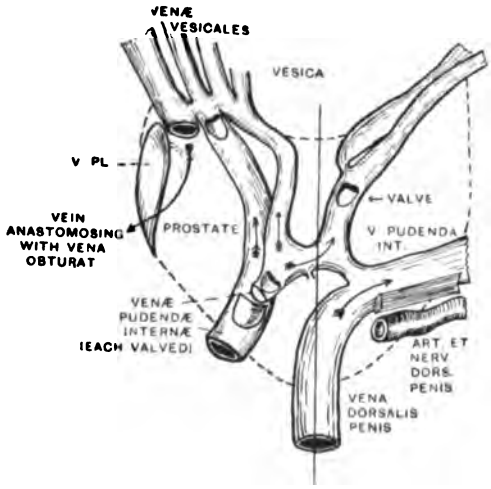


FIG. 7.—The upper surface of the prostate, showing the arrangement of the veins in a Soudanese negro.

The positions of the valves, found by splitting open all the vessels shown, are shown.

or minimised in our British text-books,[1] is well known and widely recognised elsewhere. I shall return to this matter later on, when I come to the consideration of the prostatic plexus and the capsule of the prostate.

The object of this digression is to make it clear that the internal pudic vein is usually found[2] in the fascia lunata, close beside the dorsal nerve

[1] As an illustration of the strange reluctance to recognise the true arrangement of these veins, I might refer to the recent memoir of Thomson Walker (10), in which the subject of the prostatic veins is discussed. The roots of the two internal pudic veins are represented coming from the dorsal vein of the penis (fig. 7, p. 202), but, instead of calling them "internal pudic," Thomson Walker simply describes them as "a large vein passing outwards and backwards on each side."

[2] Of course this vein is subject to great variation, like most veins of the body, and it often fails to join the internal pudic, just as the dorsal artery often comes from some other vessel.

(or the internal pudic nerve) in the whole extent of the fascia. It enters the latter between the pubo-prostatic ligament and the dorsal nerve, just behind the lower border of the subpubic ligament (LIG. ARCUATUM PUBIS): its opening is represented but not labelled in fig. 1.

As in the posterior part of its extent, so also in front, the fascia lunata is placed alongside, and as a rule is fused to, the aponeurosis of the obturator internus muscle (fig. 5) or its tendinous attachment to the pubic arch (figs. 6 and 8). The disappearance of the ischio-rectal fossa (which in the rectal triangle separates it from the levator ani) leads to its close approximation to the pubo-coccygeus (the pubic part of the levator ani), and it often happens that the fascia lunata becomes attached to the sheath of this muscle (at the base of the triangular ligament to the outer surface (fig. 5), further forward, to its lower border (fig. 6), and finally, to its anterior surface (fig. 8)).

THE TRIANGULAR LIGAMENT.

In his admirable treatise, on which I have drawn so largely for my knowledge of the literature relating to the subjects discussed in this memoir, Delbet (2) defines the triangular ligament (the so-called inferior layer) as the "aponeurosis of attachment of the erectile bodies, and, more especially, the bulb of the penis to the pubic rami—in fact, a bulbar ligament, . . . it represents an expansion of their (the erectile bodies) fibrous sheaths; it is a ligament which fixes the bulb firmly and gives it a *point d'appui* during erection" (p. 232). In addition, it forms the sheath of the deep transverse muscle and the sphincter urogenitalis. These facts are clearly shown in the section represented in fig. 6. The intimate relationship of the triangular ligament and the fascia lunata (in the human subject, but not in all Primates) can be best expressed by the statement that the triangular ligament is attached to the bone partly through the intermediation of the fasciæ lunatæ (figs. 5 and 6).

Near its anterior extremity the fascia lunata becomes attached to the posterior aspect of the ligamentum transversum pelvis of Henle (figs. 1 and 8), to the consideration of which I shall return when the capsule of the prostate comes up for discussion.

Except for the fact that it exhibits a mesial cleft, the relations of the triangular ligament in the female are identical with those of the male. A glance at Farabeuf's drawing (Rieffel, 4, p. 677) will make this plain.

THE SO-CALLED DEEP LAYER OF THE TRIANGULAR LIGAMENT.

"There is, in reality, no deep layer, but a series of formations situated some in front and above the urethra, others behind it" (Delbet, 2, p. 233).

When, in the course of a dissection of the perineum, the inferior or true triangular ligament is removed and with a sharp knife the fascia lunata (and its contents) and the membranous urethra (with its sphincter) are cut

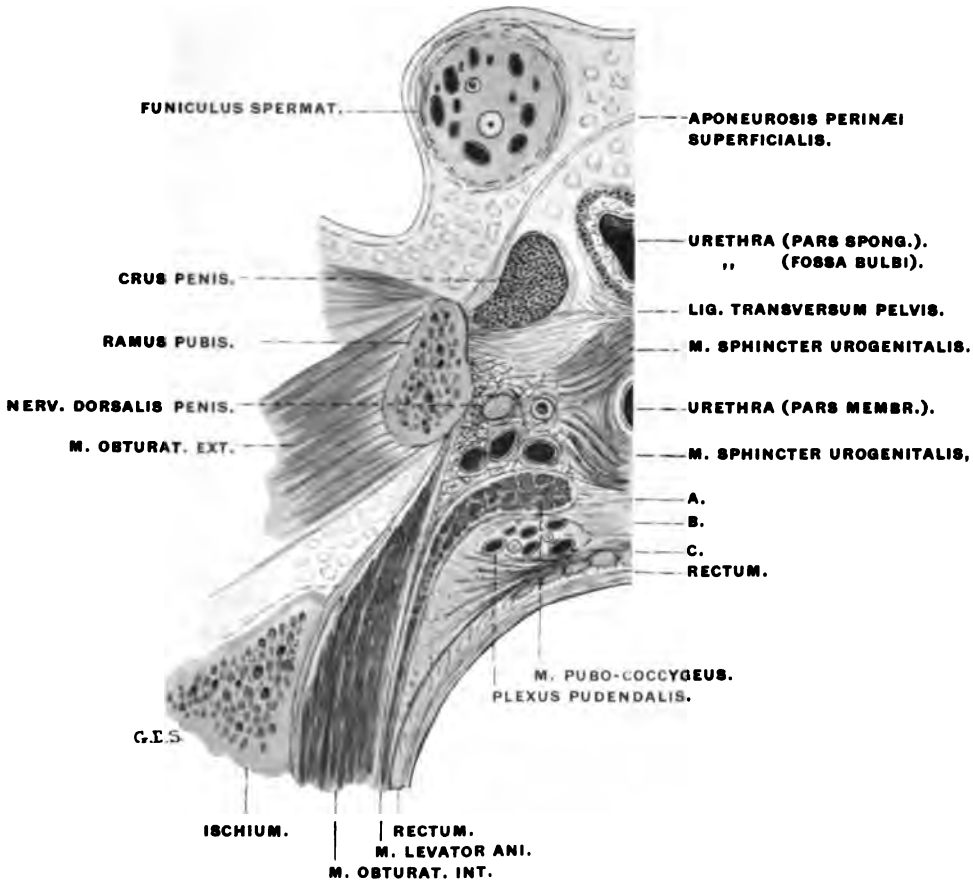


FIG. 8.—The left half of a horizontal section passing immediately below the prostate (fig. 2, E E).

The two arrows B B in fig. 9 illustrate the manner in which the urethra is cut in two places to produce the appearance shown in the figure (8)—the small oval section of the membranous urethra and the large triangular lumen of the fossa bulbi. A and B point to the perineal body, which here contains unstriped muscle bridging the gap between the mesial borders of the pubo-coccygei muscles of the two sides (only one of which, of course, is shown). C refers to longitudinal bundles of the rectal musculature, which are leaving the rectum to be inserted into the perineal body (see fig. 12, M. RECTO-URETHRAL SUPERIOR).

away, a layer of fibrous tissue is exposed (see fig. 8) which is composed of the anterior layer of the sheath of the pubo-coccygeus muscle and the perineal body (A), or rather the posterior part of the sheath of the sphincter urogenitalis, which is fused to it. This is what most anatomists call the

"deep layer of the triangular ligament." Deaver makes the useful suggestion that it would greatly simplify matters if we were to call it the forward continuation of the anal fascia. Better still, if a name is necessary, let us call it simply the aponeurosis of the levator ani.

These facts are particularly well shown in the female in Farabeuf's drawing (Rieffel, 4, p. 677), to which I have already referred.

The Levator Ani Muscle.

The detailed accounts of this muscle, which have been given by a host of writers—especially Holl (7), Kollmann (11), Peter Thompson (12), and Derry (1)—make it unnecessary for me to discuss its connections and relations at any length. The proper comprehension of the true nature of the pelvic fasciæ, however, is impossible without a clear understanding of these facts, and it is desirable to call special attention to certain features which are not, as a rule, sufficiently emphasised.

The pubic portion of the muscle (pubo-coccygeus) arises by fleshy and tendinous fibres from the back of the pubes along a line beginning immediately behind the pubic attachment of the pubo-prostatic ligament (fig. 1) and passing upward and very slightly backward to the upper part of the anterior margin of the obturator canal. The deeper layer of the sheath of this muscle becomes attached to the anterior part of the sheath of the obturator internus, which is placed beneath (external to) it (fig. 6). The superficial layer of its sheath is always thickened to a greater or less extent by the attachment to it of the lateral ligament of the bladder (fig. 5, LIG. LAT. VESICÆ; fig. 15, E E), which consists of a condensation of mesodermal tissue around the vesical plexus of veins (fig. 5). In the female there is a similar thickening of the upper aponeurosis of the pubo-coccygeus on the sides of the vagina (Rieffel, 4, fig. 415, p. 677).

Sometimes the origin of the pubo-coccygeus extends further backward along the upper margin of the obturator membrane (fig. 1, *a*) as far as the posterior margin of the obturator canal. More often, however, it is the iliac portion of the levator ani (ilio-coccygeus) which arises from this membrane, and thus closes in the compartment, which contains the obturator internus muscle.

Behind the obturator canal the line of origin of the ilio-coccygeus (fig. 1) passes vertically upward almost to the ilio-pectineal line; it then passes obliquely upward and backward near the brim of the pelvis; then it curves downward immediately in front of the sacro-iliac joint, and the sheath of the muscle or the muscle itself becomes firmly attached to the anterior margin of the great sciatic foramen, as far as the spine of the

ischium. From this extensive origin the sheet of converging muscular fibres and its sheath become attached to the triangular ligament or perineal body (fig. 5), to the anal canal and lower part of the rectum (fig. 4), to the fibrous raphé passing from the rectum to the coccyx, and to the coccyx and sacrum (fig. 15). It also forms a rectal

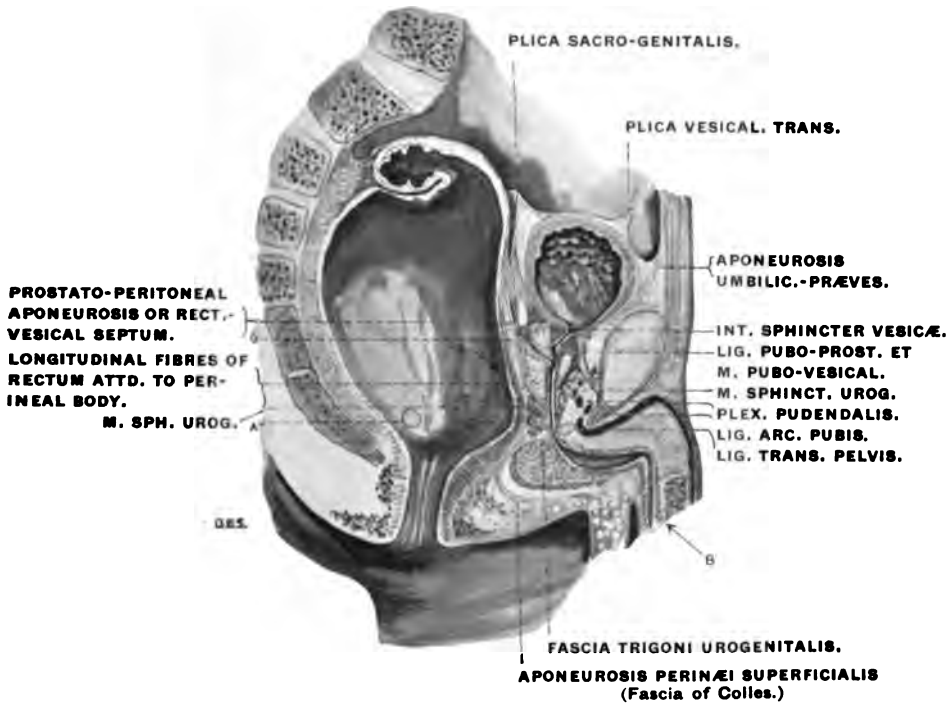


FIG. 9.—The left half of the pelvis of a Soudanese negro cut in mesial sagittal section.

This particular pelvis was chosen for representation because the rectum was naturally distended to its maximum size. The bladder also slightly distended. This has put on the stretch certain bands—the recto-vesical septum—attached to the peritoneum in the recto-vesical recess and other ligaments around the bladder and prostate that I wish to show. D is the prerectal recess filled with fat. A indicates the place where the sheath of fibrous tissue investing nerves passing direct from the fourth sacral foramen to the rectal ampulla is attached to the latter. The arrows B B indicate the plane in which the section represented in fig. 8 cuts the viscera. C C is the prerectal septum (see fig. 8, A B)—the part of the perineal body interposed between the rectum and the sphincter of the membranous urethra.

sphincter, and its sheath helps in the formation of the capsule of the prostate (fig. 5).

In other words, practically the whole pelvis, excepting only the great sciatic foramina and part of the sacrum and back of the pubes, is lined with levator ani muscle. The whole obturator internus muscle is covered

by it, and the membranous lining of the pelvis, which in its upper part is called "parietal pelvic" or "obturator" fascia, and in its lower part "visceral pelvic" fascia, is the upper sheath of the levator ani muscle, or, in parts, the muscle itself transformed into aponeurosis (fig. 3, APONEUR. OF M. ILIO-COCCYG.). For it is extremely rare to find the actual muscular tissue of the ilio-coccygeus extending upward into the tongue-shaped area between the obturator canal and the sciatic foramen (fig. 1); much more often this part of the muscle is transformed into a sheet of fibrous tissue (fig. 3), which is the so-called "obturator" or "parietal pelvic" fascia. In some cases it becomes adherent to the thin sheath of the underlying

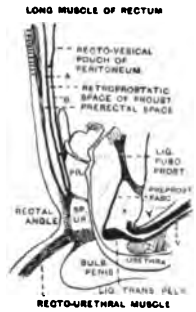


FIG. 10 is a diagrammatic representation of certain features of fig. 9.

V is the supra-urethral fascia of Delbet, which is joined to the sheaths of the upper surfaces of the corpora cavernosa (Z) and forms a bed of support for the dorsal vein of the penis. It is joined to the anterior border of the transverse ligament (LIG. TRANS. PELV.); and to the posterior border of the latter is attached the anterior part of the capsule of the prostate —the preprostatic fascia of Zuckerkandl (PREPROST. FASC.). X is the space containing the retropubic pad of fat between the latter and the subpubic ligament, Y. A and B are the two layers of the recto-vesical septum (the prostato-peritoneal aponeurosis or fascia of Denonvilliers): they are separated the one from the other by a potential cavity, the retroprostatic space of Proust, and from the rectum by an actual space filled with fat, which I have called "prerectal."

obturator muscle; but it frequently happens that the two structures are not united by any stronger bond than a thin layer of very loose areolar tissue loaded with soft fat (fig. 3, A).

In many cases the upper part of the aponeurosis of the ilio-coccygeus undergoes a still further reduction and becomes converted into a thin translucent membrane covering the obturator internus muscle. In such cases the upper border of the muscle or its (strong) aponeurosis may appear to "slip down" the pelvic wall to the line *e* (fig. 1), or lower still to the line *ad*, below the obturator canal. Either of these lines would be called an "arcus tendineus m. levatoris ani." It is quite common for the upper

border of the ilio-coccygeus to "slip down" further still, until it reaches the level of a line joining the ischial spine to the pubic attachment of the pubo-coccygeal ligament. In such a case the abbreviated ilio-coccygeus gains a new bony attachment; the muscular fibres are attached above to a tendinous band, but this does not cease at the anterior border of the ilio-coccygeus; it passes forward on the surface of the pubo-coccygeus to be attached to the pubes. This "white line" (fig. 3), to use its best-known name, is not correctly described by the designation "arcus tendineus fasciæ pelvis," because it is really a tendon of origin of the ilio-coccygeus, and has

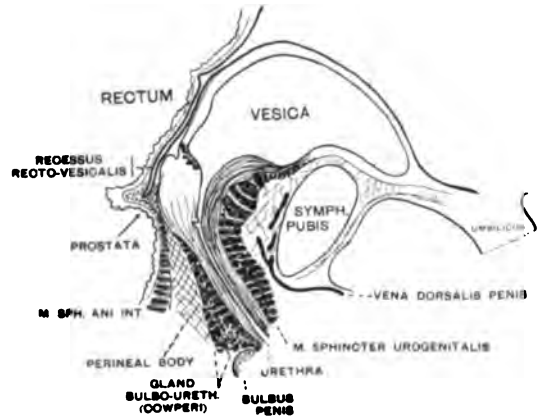


FIG. 11.—The anterior part of the mesial sagittal section of the pelvis of a male fœtus at the end of the fourth month.

This is intended to show the extent of the recto-vesical recess of peritoneum and its relationship to the recto-vesical septum of the adult (fig. 10).

at least as great a claim to the name "arcus tendineus m. levatoris ani" as either of the lines *e* or *d*, shown in fig. 1.

The fact that the lateral ligament of the bladder becomes attached to this "white line," and even contributes some tendinous fibres to it, does not alter the fact that the "white line" is essentially a tendon of the ilio-coccygeus, and that its presence or absence is determined wholly by the modifications to which this muscle is subject.

Yet a further stage in the reduction of the upper part of the aponeurosis of the ilio-coccygeus may occur—*i.e.* it may disappear; when this happens the arcus tendineus (leaving out any further unnecessary qualification) becomes the free edge of a pocket (fig. 15, HIATUS), placed between the ilio-coccygeus and either the obturator internus or, in some cases, the deeper fibres of the levator ani itself.

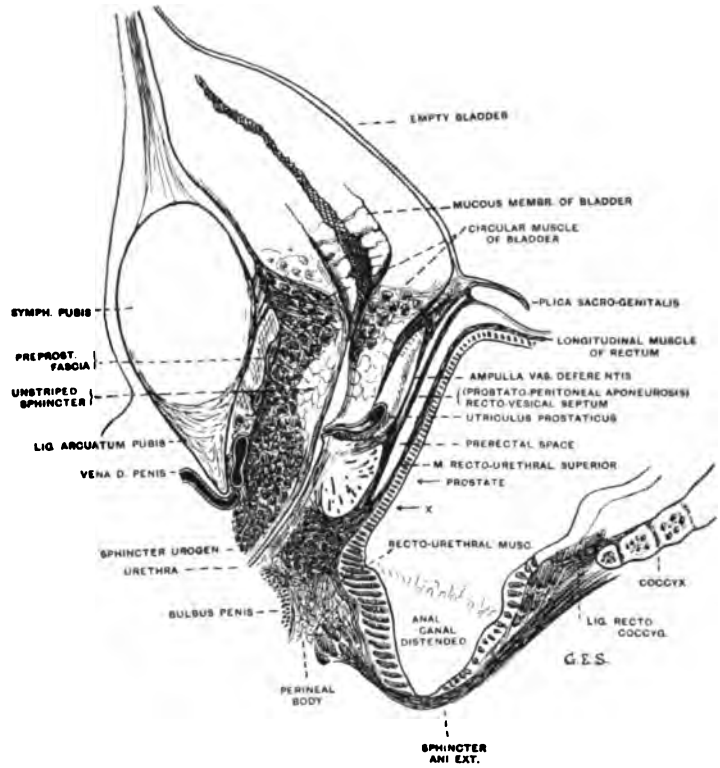


FIG. 12.—The mesial sagittal section of the pelvis of a Soudanese negro (æt. 30 ann.), showing an infantile type of bladder.[1]

The sphincters of the bladder and urethra are shown with exceptional distinctness. Compare Kallacher's diagram in Eberth, 6, p. 192; the figures in Delbet, 2, p. 151; and Thomson Walker, 10, p. 196. X is the place where the longitudinal musculature on the anterior surface to the rectum becomes inserted into the perineal body (M. RECTO-URETHRAL. SUPERIOR).

[1] This infantile type of bladder—a torpedo-shaped organ, projecting well above the pubes, even when quite empty—seems to be very common in Soudanese negroes. I have seen a very large number of instances of this peculiarity; and my colleague, Dr Roy Dobbin, professor of gynæcology, tells me that he is frequently troubled by finding the bladder in his way, when doing pelvic operations by the suprapubic route.

This section exhibits a condition of funnel-shaped distension of the rectal canal from above. The specimen is the only one (of many hundreds of bodies fixed in formalin that I have examined in Cairo) in which I have seen such distension, although Birmingham (writing in Cunningham's *Text-Book of Anatomy*, 1902) regarded it as a common, if not usual occurrence. To quote his own words: "It is probable that, when the rectum is distended, the upper part of the anal canal is often, if not usually, occupied by the wedge-shaped lower end of the contained fæcal mass" (p. 1041). I believe this specimen to be altogether exceptional, because the evidence of a very large series of recta, examined in every stage of natural distension, shows that, as a rule, the walls of the anal canal *in its whole extent* are tightly pressed together (figs. 4 and 9), and no part of the canal is more completely

This pocket seems to be identical with the recess called by Schwalbe "hiatus pelvicus lateralis."[1]

I have devoted special attention to the hiatus of Schwalbe, because its presence affords such a clear demonstration of the inaccuracy of the common account of the "levator ani and visceral pelvic fascia *arising from* the obturator or parietal pelvic fascia." Instead of arising from the lateral pelvic wall (or the fascia on the surface of the obturator internus), in such cases the levator ani muscle and its fascia are separated from the pelvic wall by the hiatus of Schwalbe.

Instead of describing a parietal and a visceral pelvic fascia, it would be more correct to say that the pelvic cavity is lined by the aponeurosis of the levator ani muscle, which is subject to great variations in thickness and texture in different subjects, and in its various parts in the same subject, and often exhibits deficiencies where the obturator muscle and its thin aponeurosis become exposed.

The Perineal Body (Centrum tendineum perinæi).

The space between the membranous urethra and the rectum (figs. 8, 9, 10, 11, and 12) is occupied by a solid mass of tissue which Macalister (13, fig. 570, p. 445) and Keith (14, p. 139) call the "perineal body"; Keibel calls it the "septum urorectale" (see Eberth, 6, fig. 243, p. 296): but the most complete

closed than the upper end—or internum—of the anal canal, where the pubo-coccygeus (sphincter recti) presses its lateral walls firmly one against the other.

Such evidence can be obtained in the dissecting-room, when bodies fixed with formalin are used, if the dissectors are instructed *not* to attempt to pack the anus and rectum.

[1] As I am not acquainted with Schwalbe's account of this hiatus, I cannot be sure of the identity of the pocket; but the following quotations from Delbet (2, p. 237) and Rieffel (4, p. 680) can refer only to this one structure:—

"En avant, à quelque distance en arrière de la gouttière sous-pubienne, on aperçoit souvent un orifice laissant voir à nu les fibres du releveur sous-jacent. C'est l'hiatus pelvien latéral de Schwalbe. Par cet orifice on voit parfois l'intestin s'engager, formant hernie" (p. 237), and "il existerait même, entre cet orifice (obturator canal) et l'arcus aponéorotique, une lacune semilunaire à convexité antérieure, l'hiatus pelvicus lateralis de Schwalbe et Hoffmann, par lequel passeraient, selon Drappier, quelques hernies périnéales de la vessie. Pour ma part, je n'ai jamais vu un pareil hiatus" (p. 680).

Rieffel's admission that he has never seen such a hiatus is very surprising, because its presence is by no means a rare occurrence. Although I have never seen a hernia into the hiatus, in several cases I have found it occupied by a mass of fat as large as the distal segment of a man's thumb. Looking at fig. 3, and imagining the upper aponeurotic part of the ilio-coccygeus muscle to have disappeared, the reader will realise that a hernia into the hiatus would occupy the space A immediately above the ischio-rectal fossa.

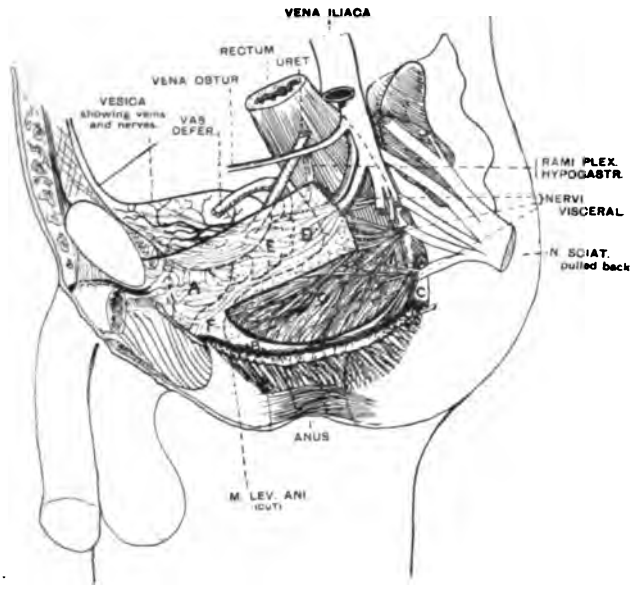
When some of the fibres of the levator ani pass up to a higher level than the definitely formed "white line" (fig. 3, M. ILIO-COCCYG. (PARS SUPERIOR)), the hiatus, if present, would be found between the main mass of the ilio-coccygeus and the "pars superior." In my experience it is much commoner to find it in those cases where there are no superior fibres, and then the outer wall of the hiatus is formed by the obturator internus.

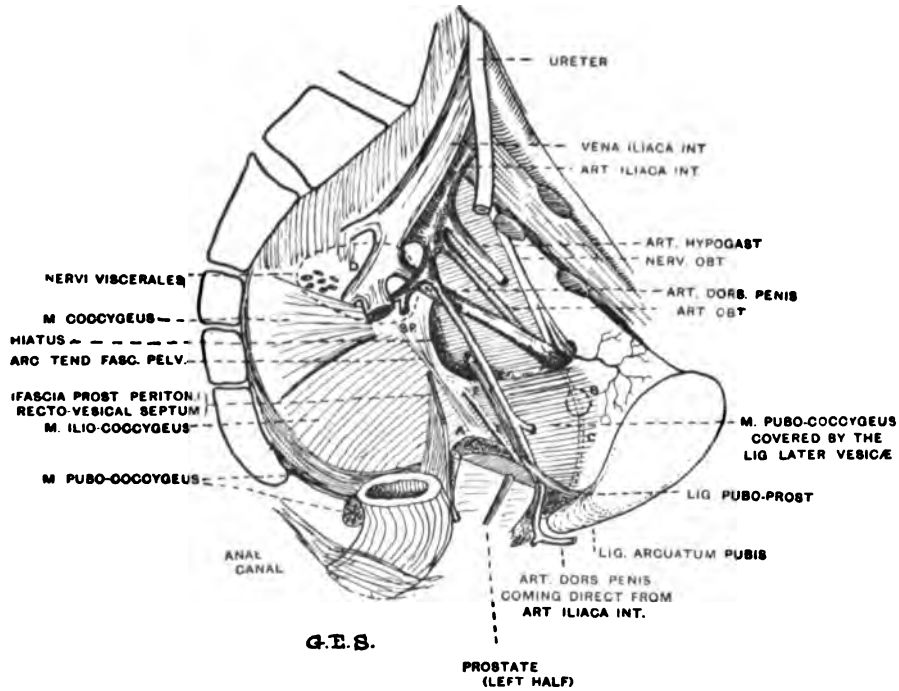
account of it that I know of is given by Delbet (2, pp. 228 *et seq.*), who bases his description of the "noyau fibreux central du périnée," as he calls it, on the researches of Hogge (*Ann.*, génito-urin., 1904). He describes it as a septum interposed between the rectum and the urethra, composed of unstriped muscle superiorly (fig. 8, A, B) and of fibrous tissue inferiorly (fig. 9), where the base of the triangular ligament (FASCIA TRIGONI UROGENITALIS) forms part of it. It extends downward as far as the skin of the perineum, upward as far as the bottom of the recto-vesical recess of peritoneum *in the fœtus* (fig. 11), and, laterally, as far as the mesial borders of the pubo-coccygei muscles (fig. 8). Delbet states further (2, p. 228) that "it adjoins the lower fourth of the back of the prostate (figs. 9 and 10), and insinuates itself between the two halves of the sphincter urogenitalis (see fig. 8) to the urethra, and becomes continuous with the mesial fibrous raphé of the bulb of the penis and the bulbo-cavernosus." He adds that the unbroken mass of mesoderm, which unites the urethra to the rectum in the fœtus, becomes fenestrated, when the fibres of the urogenital sphincter and the deep transversus perinæi muscles develop within it (see figs. 8, 9, 11, and 12). The mesial anterior longitudinal fibres of the rectum pass downward to be inserted into the upper end of the perineal body (figs. 8, 9, 10, and 12, X), and longitudinal fibres passing upward and forward from the front of the anal canal—the so-called recto-urethral muscle of Roux—go to be inserted into this same mass behind the urogenital sphincter (figs. 10 and 12). Thus the rectum becomes fixed to the membranous urethra; this explains the "rectal angle" (fig. 11).

Wood Jones (quoted by Keith, 14, p. 145; see also fig. 122, p. 150, and fig. 144, p. 139) has shown that the recto-urethral muscle is a remnant of the recto-cloacal communication in the embryo.

Seeing that the so-called recto-urethral muscle of Roux really comes from the wall of the anal canal, it would be more appropriate to call it "ano-urethral" or "ano-central," and reserve the term recto-urethral, or, better, "recto-central" for the upper band that I have described coming from the true rectum. For the purposes of the present memoir, and at the same time to avoid innovation in nomenclature, I shall distinguish the latter as the musculus recto-urethralis superior. In the specimen represented in fig. 9 it consisted of two bands each 1 millimetre thick, one 3 millimetres broad, and the other 2 millimetres. I have found it in all the subjects examined.

Delbet describes the upper part of the perineal body in these terms: "It is composed of unstriped muscle, thrown like a bridge across the space between the borders of the levatores ani (see my fig. 8) in front of the rectum; it forms a band which encircles the anterior aspect of the latter—the prerectal muscle (fig. 8, A, B). The anterior part of this superior





These figures are only inserted for reference, and will be repeated in part ii. of this paper.

PROFESSOR G. ELLIOT SMITH.

extremity affords an attachment for the aponeuroses, which pass upwards to the rectal and vesico-genital recesses of the peritoneum and form the prostato-peritoneal aponeurosis of Denonvilliers; the posterior part affords an insertion to the anterior longitudinal fibres of the rectum" (2, p. 229). This is a precise account of the conditions represented in figs. 8, 9, 10, and 12.

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AN UNUSUAL DUODENAL DIVERTICULUM.

By C. M. JACKSON, M.S., M.D., *Professor of Anatomy in the University of Missouri.*

THE duodenal diverticulum to be described was found in the body of a male aged 50, in making a series of transverse sections after hardening by intravascular injection of formalin. The cause of death was pneumonia.

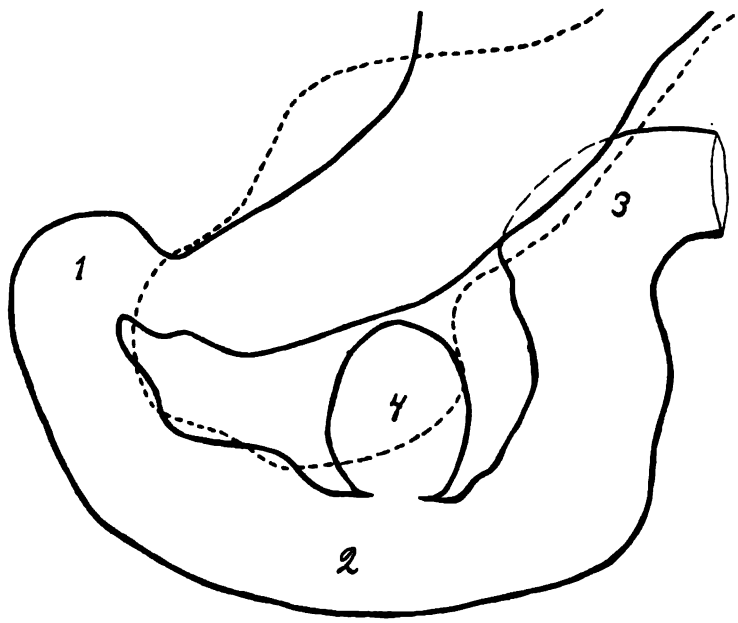


FIG. 1.—Diagram showing the relations of the duodenal diverticulum, anterior view. Two-thirds natural size. The entire duodenum and the pyloric portion of the stomach are represented. Pancreas shown in dotted outline: 1, first part of duodenum; 2, transverse duodenum; 3, duodeno-jejunal angle; 4. duodenal diverticulum.

The diverticulum, as shown in fig. 1, extends upward from the upper wall of the transverse duodenum. The sac measures about 3·5 cm. in the vertical direction, 3 cm. in transverse width, and 2 cm. antero-posteriorly (being deepest in this direction in the lower part of the sac). The neck of the sac is constricted, the aperture of communication with the duodenum measuring about 5 mm. in diameter.

The diverticulum is in contact, posteriorly, with the aorta and vena cava. Anteriorly, it is in contact with the superior mesenteric artery and vein below, and with the posterior surface of the head of the pancreas above. The inferior pancreatico-duodenal artery and vein, arising from the superior mesenteric, pass to the right just in front of the upper portion of the sac, giving off a large artery and vein which enter the wall of the sac. The diverticulum is also supplied with other small branches. The sac shows no relation to the pancreatic or bile ducts.

In order to study the minute structure, various portions of the sac were removed, embedded in paraffin, and cut into sections 5μ thick. The wall of the sac is thin (·7 to ·8 mm. thick), and in general resembles the neighbouring duodenum in structure, differing in certain respects, however. It is lined by mucous membrane, somewhat reduced in thickness, and is limited, externally, by a thin fibrous tunic. Between these is a muscular coat, only ·1 mm. to ·15 mm. in thickness, but everywhere distinct.

The inner (and usually larger) portion of this coat is made up entirely of plain muscle arranged in two distinct layers of fibres at right angles to each other in direction. This portion of the muscular coat, as seen in sections through the junction of the sac with the duodenum, represents a hypertrophied muscularis mucosæ. It is three to five times as thick as that in the adjacent duodenal wall, with which it is continuous.

The outer portion of the muscular coat in the wall of the sac is constant, but somewhat variable in thickness. It is made up largely of white fibrous tissue interspersed with plain muscle fibres, partly longitudinal and partly transverse in direction. The outer portion of the coat, at the neck of the sac, is continuous with the tunica muscularis of the duodenum. It is not arranged in layers, however, and usually not separated from the inner portion of the muscular coat in the sac by anything corresponding to the submucous coat of the duodenum.

Intestinal diverticula are not uncommon, and I have found in all eighteen cases of duodenal diverticula mentioned in the literature. The present case presents certain unusual features, however. (1) In *size* it is, with a single exception, the largest duodenal diverticulum on record. The usual size is that of a pigeon's egg, or smaller. (2) In *position* only two of the cases described were found in the transverse duodenum. All others were in the first or second portions of the duodenum, and usually closely associated with the mouths of the bile and pancreatic ducts. (3) In *structure* all previous duodenal diverticula have been described as of the *false* variety, *i.e.*, made up of mucous membrane only. In this case, however, in addition to a hypertrophied muscularis mucosæ, a rudimentary tunica muscularis is present.

A CASE OF ACCESSORY LOBE OF THE RIGHT LUNG.

By G. C. E. SIMPSON, B.A., M.B., B.C. (Cantab.), B.Sc. (Lond.). (*From the School of Anatomy, Cambridge University.*)

ACCESSORY lobes of the lungs appear to be sufficiently rare to justify a report of the following case, which was found on opening the thorax of a full-term fœtus.

In the right pleural cavity a large tumour lay on the diaphragm between it and the base of the right lung. It measured 2 inches in length and

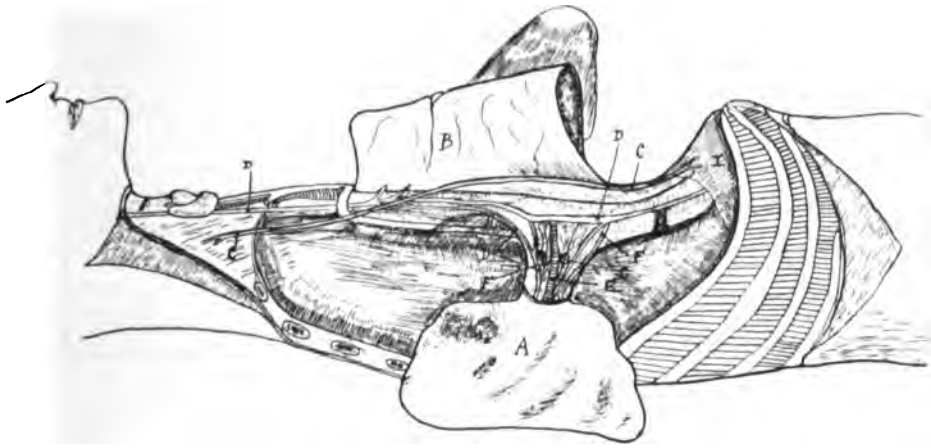


FIG. 1.

A, accessory lobe; B, right lung; C, phrenic nerve; D, right vagus nerve and plexus; E, artery to accessory lobe; F, veins from accessory lobe; G, lymphatic gland; H, œsophagus (covered by pleura); I, diaphragm.

1¼ inches in breadth, and was completely invested by pleura. The tumour was attached by a long but narrow pedicle to the mediastinal pleura in contact with the œsophagus at the level of the tenth thoracic vertebra. The right lung was rather small, being 1¾ inches long, the left measured 2¼ inches; otherwise, both lungs were normal and presented the usual lobes and fissures. All the other organs appeared to be normal.

The tumour had on its lateral and posterior aspects impressions corresponding to the last four ribs, and was indented on its upper aspect by the base of the right lung, while the lower concave surface was moulded on to

the diaphragm. There were small cysts visible on its surface, and when incised its structure was seen to be markedly cystic.

The pedicle contained:—

(1) An artery, equal in size to the internal carotid, which sprang from the aorta at the level of the tenth thoracic vertebra and crossed behind the œsophagus.
(2) Several veins which joined œsophageal veins and terminated in the vena azygos major.
(3) Some lymphatic vessels and small lymphatic glands.
(4) A plexus of nerves derived from both vagus nerves.

No semblance of a bronchus was detected.

Histological Examination.

A piece taken from the border furthest from the hilum was hardened in Muller's fluid and submitted to microscopical examination: the tissue proved difficult to stain, as the fœtus had been but roughly preserved for anatomical purposes.

The tissue was mainly composed of alveoli of varying sizes lined by cubical or flattened epithelium; elastic tissue and a well-marked network of blood vessels were present in the walls of the alveoli. In places the walls of the alveoli appeared to have given way, forming large cavities, with partial septa indicating the previous subdivision. The appearance was similar to that seen in emphysematous lungs. The epithelium presented a very degenerate appearance: in some places it was detached or absent, while in others it was disposed in two or three layers. Most of the alveoli were, however, lined by a single layer of cubical cells. The alveolar cavities contained a large amount of debris, mainly composed of epithelial cells, but in places blood corpuscles were also present.

In addition to the alveoli there were a large number of cystic cavities and long-branched canals. In the recent state these contained fluid: when examined microscopically, the larger cysts exhibited a thick connective tissue wall containing elastic elements, and for the most part destitute of epithelial lining. In the smaller cysts and in the canals the walls were of a similar character, but in places were lined by a layer of columnar epithelium. In nearly all there was a large amount of debris partially composed of desquamated cells of columnar type.

Plates of cartilage were found in the walls of a few of these canals, but apparently only in those furthest from the surface. Some of the finer canals were seen to expand into the alveoli. The groundwork was composed of connective tissue and was exceedingly vascular.

These appearances suggest that the tumour was composed of lung tissue which had undergone cystic degeneration. The alveoli with their cubical epithelium and elastic groundwork correspond to the alveoli of the lung, while the canals with their columnar epithelium and cartilaginous plates represent bronchi. The cysts are apparently bronchial in origin.

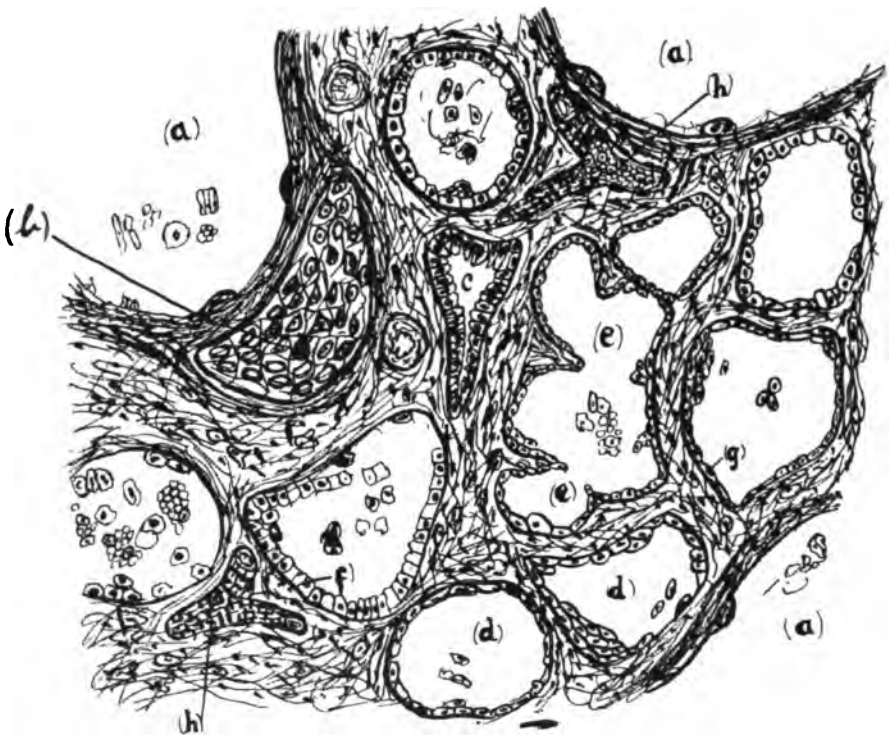


FIG. 2.

a, large cysts (bronchi); *b*, cartilage in wall of bronchus; *c*, bronchiole (?); *d*, alveoli; *e*, alveolus with walls breaking down; *f*, cubical epithelium; *g*, flattened epithelium; *h*, blood vessels.

An examination of the literature dealing with anomalies of the lungs showed that, in most of the recorded cases of abnormal division of these organs, the bronchus of the abnormal lobe was in direct continuity with the main bronchus. The cardiac lobe, constant in many animals and frequently observed in man, is of this type, as is also an accessory lobe in connection with the upper part of the right lung, which from its association with an abnormal vena azygos major has received the name of the azygos lobe.

Collins (1) gives an excellent report of one such case and refers to others,

including one case recorded by Wrisberg, in which a similar lobe was found on the left side in connection with a left vena azygos major.

There are also a few cases recorded similar to that under consideration in which the bronchus of the accessory lobe had no connection whatever with the lungs or air passages. The morphology of these cases is of great interest, and a brief abstract of these follows.

In Rektorzik's (2) case—a girl aged 18—an accessory lobe was found between the base of the left lung and the diaphragm. It had no connection with the lung, and its artery sprang from the thoracic aorta near the origin of the seventh intercostal artery. The vein joined the hemiazygos vein. The accessory lobe, together with its bundle of supplying vessels, being completely clothed by pleura, was freely movable. Its structure was alveolar; the bronchioles were easily identified, as ciliated epithelium was present in them.

Rokitanski (3) found an accessory lobe in a child of 3 months old, lying between the diaphragm and the base of the left lung, the lobulation of which was normal. It was supplied by two arteries which sprang from the aorta near the tenth intercostal artery; the vein joined the vena azygos. In this case the accessory lobe does not appear to have been freely movable.

Similar cases in infants, both occurring on the left side, have been described by Rüge (4) and Lawrence Humphry (5). Humphry's specimen is now in the Pathological Museum at Cambridge.

Hugenin and Sorel (6) also described a case on the left side, and Darier (7) made a careful histological examination of it. His account of the specimen, which was in a state of good preservation, agrees very closely with the appearances presented by mine, with the important difference that he could not find cartilage in the walls of the bronchi.

Vogel (8) carefully examined two cases in the museum at Bayern, one of which had been previously reported by Dubler. These presented the same appearances as the other specimens, consisting mainly of a network of alveoli with elastic tissue in their walls, and lined by flattened epithelium. Among these alveoli were bronchi lined by columnar ciliated epithelium and with cartilaginous plates embedded in their walls. In both cases the tumour was situated in the abdominal cavity lying in the retroperitoneal tissue immediately below the diaphragm. In one of them a diverticulum, conforming in type to the bronchi, passed upwards through the aortic opening in the diaphragm to end blindly in the thorax, and served to show the thoracic origin of this tumour, which by some mistake of development had attained an abdominal situation.

The chief interest in Vogel's work, however, lies not in the position of the abnormal lobes but in the result of his examination of the bronchial

trees of the lungs of these cases. He showed that in each case the bronchial tree was deficient, one of its main branches being absent on the left side; and so he established the fact that his cases, and probably all such cases, were accessory lobes and not accessory lungs. For a further study of this point I must refer to his paper and to Schaffner's (9) paper on the relations of the inferior accessory lobes to the bronchial trees.

All these cases except Vogel's have occurred in the lower part of the left pleural cavity, and it is suggested that the condition may be due in some way to pressure exerted on the growing lung by the aorta during its development.

Humphry has taken this view, and gives excellent reasons for it in his paper (5).

Vogel's two cases, however, cannot be due to this cause, but would rather appear to be connected with the development of the diaphragm; and recent work in embryology shows that the developing lungs are in the early stages very intimately related to the diaphragm, or rather to the septum transversum.

My case again cannot have been caused by the pressure of the developing aorta, and there was no anomalous condition of the vena azygos major to account for it. The occurrence of this case in the right pleural cavity suggests that the similar cases on the left side may not necessarily be connected with the aorta, and the true explanation of the cases may perhaps be found when embryologists have thrown more light upon the development of the diaphragm and the lungs.

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FURTHER OBSERVATIONS ON THE DEVELOPMENT OF THE TEETH OF THE AUSTRALIAN ABORIGINAL. By W. RAMSAY SMITH, D.Sc., M.B., C.M., F.R.S.E., *Adelaide.*

WHEN examining some young aboriginals' skulls and jaws shown to me by Dr Randell of Adelaide, I noticed some remarkable appearances that they presented. By Dr Randell's kindness I have been able to take photographs illustrating the conditions and to describe them.

The appearances in the Australian aboriginal differ so much from the usual descriptions, and are also so important from the point of view of evolution, that one might well be excused if even a large amount of detail should occur in the descriptions of specimens. Further, such materials are sufficiently uncommon to be valuable for comparative purposes even if nothing were attempted beyond making careful and accurate descriptions of the specimens. I shall venture, however, to offer some remarks and commentaries chiefly by way of suggesting lines of comparison and with the view of prompting further investigation into a very interesting subject.

It may be well to state here the special points that struck one's attention and seemed to demand further study when examining these specimens. They were (1) the peculiarities of the "gubernacular canals"—the passages leading to the tooth sacs of the permanent incisors and canines and the bicuspids; (2) the grooves for the enamel germs, which occur between the first and second and between the second and third molars; (3) the mode of development and eruption of the second and third upper molars; (4) the places of the jaws where osseous growth specially occurs, and particularly the position of the transverse palatine suture at the various stages of development of the molars. With these preliminaries I pass to a description of the specimens.

No. 1. The skull of a subject presumably about five years old (fig. 1). The milk incisors and the left milk canine have dropped out. The central permanent incisors are coming in. They are seen to occupy the whole width of the space formerly occupied by the central and lateral milk incisors, and the septa between the alveoli of the centrals and laterals are being absorbed in front of the erupting teeth. The gubernacular canals of the permanent teeth are seen internal to the incisors and the canines. The central incisor canal is largest, the lateral is next in size, and the canine

canal is shown by a minute round opening. Internal to each canine tooth there is a swelling marking the position of the non-erupted permanent canine. It would be impossible to speak with any confidence regarding the gubernacular canals of other teeth without extracting the milk molars. All the milk molars are present. On the anterior external margin of the first right milk molar there is a cusp of mammillary appearance, midway between the neck and the grinding surface. The milk molars and the right



FIG. 1.

canine are much worn. The first molars had nearly cut the gum. The second molars are facing backwards and slightly outwards. Their crowns are fully formed. These second molar teeth are not seen in the photograph.

Between the first and second molar, on each side, there is a deep grooving of the bone forming a canal about 2 mm. in diameter. This is the groove for the dental lamina.

The photograph shows appearances suggesting that the maxillo-premaxillary sutures can be traced as far as to the canine sockets. This is deceptive, since the outer two-thirds or more of the lines is formed by a groove for a blood vessel.

No. 2. The upper jaw of a subject presumably about seven years old (fig. 2). The permanent central incisors are making their way through the jaw. They have penetrated into the sockets of the central and lateral milk incisors, taking up the whole width of these, and the partitions between these alveoli and the gubernacular canals have been absorbed. The lateral incisors are also erupting behind and external to them. Their erupting edges are showing through the gubernacular canals. The milk canines have fallen out. The gubernacular openings are seen internal to



FIG. 2.

their alveoli. The permanent canines are each causing a swelling internal to the lingual root of the first milk molar. The gubernacular canal of the first right bicuspid is a minute opening on the alveolar border anteriorly and internally to the lingual root of the first milk molar. The milk molars, with the exception of the first left, are all present, and are worn. The first permanent molars are slightly worn.

The second molars are just emerging through the bone. Here, as in other cases, the enamel surface of each of these teeth looks backwards, at first almost directly backwards, and slightly outwards. The bone becomes "eroded" on the posterior aspect of the maxilla. It is a point to be decided, however, whether these teeth are ever entirely covered by bone in the

normal course of development. The tooth then gradually comes, in the course of growth and eruption, to look downwards. Its roots in normal circumstances are not developed until the "long axis" of the tooth has assumed the vertical position.

The groove for the dental lamina between the first and second molars in this specimen is large, measuring 3 mm. in diameter on each side.

No. 3. The skull of a subject presumably about eleven years old. The permanent incisors, canines, and first bicuspids had come. The second milk molars are worn. The gubernacular canal of the second bicuspid is a minute opening internal to the middle part of the second left milk molar. A bristle passes down as far as to where the tooth sac should be. It may be noted that a bristle passed into a vascular canal passes only a short way



FIG. 3.

c., gubernacular canal of permanent canine; *i.*, socket of temporary incisor; *i.p.*, sac of permanent incisor; *c.p.*, sac of permanent canine.

into the bone, while it can be passed for a distance of ten millimetres or more along a gubernacular canal.

The first molars are worn. The second molars are absent, but their sockets are very large and show commencing subdivision for roots. The third molars look backwards and outwards and have not erupted. The grooves between the second and third molars are 3 mm. in diameter.

No. 4. The lower jaw from a subject presumably about five years old (fig. 3). The milk incisors and canines have dropped out. The milk molars are worn. The first permanent molars have not erupted. They are below the level of the upper margin of the jawbone. The gubernacular canals of the incisors and canines are well marked. Those of the central incisors are large. The jaw has been broken across through the right canine socket. A bristle passed into the small opening between the canine socket and the lingual root of the first milk molar, goes along a canal

about 10 mm. in length and reaches the large sac of the permanent canine which occupies the front and lower portion of the jaw. A bristle passed into the small opening between the sockets of the canine and the lateral incisor reaches the sac of the lateral incisor which occupies the upper and posterior portion of the jaw. The other foramina similarly lead into the sacs containing the developing permanent incisors and canines. It is clear from this specimen, as well as from many others, that the statement usually made regarding the relative positions of the milk and permanent teeth is wrong, at any rate as applied to the Australian aboriginal. The permanent teeth do not all develop in sacs behind the temporary teeth.

Slit-like foramina occur in the alveolar border of the jaw immediately internal to the milk molars in this specimen. They are so small that it is difficult to say which of them are gubernacular canals of the first bicuspids. In the case of the second right bicuspid, however, the canal opens on the narrow ridge at the antero-internal boundary of the socket of the first molar. On the left side the canal opens in a corresponding spot.

The grooves for the dental luminæ between the first and second molars are well marked. On the right side the groove is 4 mm. wide. On the left side it is 3 mm. wide.

No. 5. The lower jaw of a subject presumably about seven years old (fig. 4). This presents a very fine study of the gubernacular canals. The central permanent incisors have dropped out. The lateral incisors are erupting, the right being more advanced than the left. The premolars are still present. The sockets for the first molars are divided. The gubernacular canals of the permanent canines and the left lateral permanent incisor are well marked. The canals of the second bicuspids are minute, but are well marked. They open at the inner end of the septa between the last premolars and the first molars, a very common position for the canals of these teeth. The canal of the first left bicuspid opens on the jaw opposite to the posterior root of the first milk molar, which will be found to be the usual place for this canal. On the right side the corresponding canal opens in a similar position, but it is slit-like instead of being round. These two canals are relatively farther forward than those of the second bicuspids, and in the photograph the one on the right side is obscured by the crown of the milk molar.

In this specimen the groove between the first and second molar is slightly marked on the left side, and not at all on the right.

No. 6. The lower jaw of a subject presumably about eleven years old. The permanent incisors had been present. The permanent canines have been accidentally broken across. The first bicuspids had erupted: their sockets show little if any appearance of division. The socket of the second

left bicuspid is large, and suggests that a tooth was in the "ballooned" stage. The second milk molar persists on the right side, which is a somewhat remarkable fact considering that both canines are fully erupted. There is no appearance of a gubernacular canal for the bicuspid that is to replace the second right milk molar, and one would like to know whether this tooth is present in the jaw. The first molar on the left side has dropped out: its sockets are well marked. On the right side the tooth is in its place, and its crown is worn. The second molars have not erupted. On the right side the tooth socket is very large and undivided, suggesting

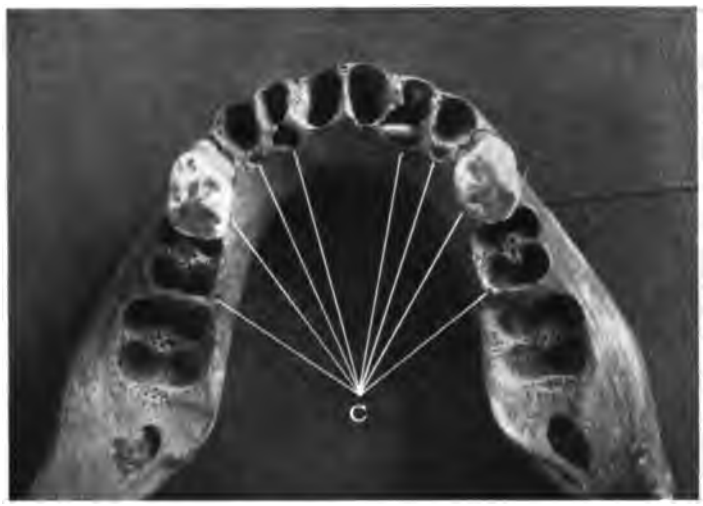


FIG. 4.
C, gubernacular canals.

very extensive "ballooning" of the tooth. The non-constriction into roots shows that the tooth, like the one on the left side, had not fully erupted. The septum between it and the first molar is so deficient on both sides, by proximity of the teeth, that no grooving would be shown. On the left side the groove between the second and third molars is 3 mm. wide. On the right side it is 2 mm. wide.

These descriptions furnish sufficient ground on which to base some general remarks regarding the special points mentioned above. To these I may refer in some detail.

1. *Gubernacular Canals.*—These specimens show that the iter dentis or gubernacular canal is at times very large in the aboriginal. They show that its occurrence is common or constant in connection with the incisors

and canines in the form of a single round or irregular-shaped opening. The canal in the case of the bicuspids is usually small, and the opening is round or slit-like or irregular in shape and is situated very near the alveolus. While the opening is sometimes directly behind the incisors and canines, this position is not invariable. It is very frequently in a line with the septum, between the milk tooth from whose sac it was developed and the tooth immediately behind that one, as if there were a tendency (which increases the farther back the teeth are) for the permanent incisors and canines and the bicuspids to develop farther back in the jaws than their milk predecessors. This shows how much greater the growth in the jaw is in the posterior than in the anterior part.

I cannot say to what extent Tomes's statement applies to the aboriginal, that the gubernacula of the bicuspids unite with the periosteum of the alveoli of their deciduous predecessors. I have not found this condition existing in any case I have examined. Besides, the statement is not universally true in the case of the white subject. In nearly every case in which I have found the gubernacular canal I have traced it from the tooth sac to the surface of the jaw in a position corresponding to what I have described in the aboriginal. On the other hand, in the white subject I have found large gubernacular canals opening half-way down the sockets of the canine teeth.

These specimens show that the gubernaculum takes no share in directing the course of the erupting permanent tooth through the jaw and the gum, any more than it does in directing the temporary tooth. What, then, is the function of these large gubernacular canals? The question prompts itself: To what extent is the developing tooth nourished by vascular structures passing through them? I think it is indubitable that there is a distinct and definite relation between the size of the gubernacular canals and the size or rapidity of growth of the teeth to which they are severally related. The absolutely largest openings are observed in the case of the incisor canals at the time when the teeth are most actively erupting.

It is to be noted that but little attention appears to have been given to the gross anatomy of these structures. In many illustrations of jaws in which one would expect to find them they are omitted altogether. In others they are imperfectly depicted. These facts are not surprising when one considers their minute size in many cases, and their peculiar disposition. It is interesting to note that in Cloquet's *Manuel d'Anatomie Descriptive*, plate xiv., fig. 8, they are represented with great regularity on the lingual aspect of the incisors, canines, and first milk molars, and that the dotted lines of reference also run to similar positions with reference to the second milk molar and the non-erupted first permanent molar. This last is

obviously a mistake, since there is no iter or foramen in the drawing, which shows, however, a well-marked groove in the bone between the second premolar and the first molar. In the text (p. 49) Cloquet gives a very good description of the manner of eruption of the permanent teeth, in the course of which he makes reference to these canals. He says: "The gubernaculum, in order to reach the gum, passes by a small opening which is found on the maxillary bone, behind each milk tooth, on the posterior part of the alveolar border. These small foramina are easily seen on a level with the incisors and canines." Apart from his general reference to "each milk tooth," he does not mention the milk molars, and one is left in doubt as to whether he really meant to describe the itinera dentium of the bicuspids or not.

Morris gives a drawing (*A Treatise on Anatomy*, p. 78) of the hard palate of a child five years old, and says: "The following points are readily recognised . . . behind the incisor teeth four small openings known as the gubernacular canals." There is no sign of any canals behind the canines or other teeth, nor does he make any reference to such in the text.

Tomes here and there shows them; but some illustrations, in which one would expect to find them, do not show them at all.

In the young white subject I have seen the canals very close to the alveolus, in fact opening almost into the sockets of the temporary teeth.

2. *The Grooves for the Dental Laminæ.*—These pass from the first to the second and from the second to the third molars, and are well seen in most of these specimens. I can find very little reference to these structures in text-books. As I have remarked above, they are shown in a drawing by Cloquet. Usually these grooves, in both jaws, are deep, and form, in section, somewhat more than a semicircle, and pass backwards and slightly outwards about midway between the labial and lingual margins of the alveolar border of the jaw.

3. *The Mode of Eruption of the Second and Third Molars in the Upper Jaw.*—This will be evident from an examination of these and other specimens from aboriginals; and from the fact that I have failed to find any exception to it, the probability is that it is a racial character. In all the specimens I have examined, and in illustrations in text-books, these unerupted teeth in the white subject do not by any means look backwards as in the aboriginal. They look almost, if not altogether, directly downwards. If for any reason the roots of these teeth should develop before the tooth has assumed its final position with reference to the jaw—in other words, if it grows to full size but fails to come to the vertical position—one can readily see how impaction may occur between its growing roots and

the roots of the tooth immediately in front of it. This explains how the second molar may become impacted with the first, or the third with the second. Again, if the tooth continues to grow in its first position, it may erupt and be found with its crown against the pterygoid plate.

In the lower jaw of the aboriginal the second and third unerupted molars look upwards and slightly forwards, much in the same manner as they do in the white.

4. *It would appear that the chief additions to the Upper Jaw occur chiefly in two places*: (1) at a point at or near the anterior part of the alveolus of the canine tooth, and (2) near the posterior portion of the alveolar border of the maxilla and the part close to the transverse palatine suture. This last place of growth is shown by the mode of eruption of the molars, and also by the position of the suture with reference to the successive molars as they make their appearance in their permanent positions. The position of the transverse palatine suture at the various stages of development appears, however, to have been but little studied. One can gather some ideas on the subject from an examination of drawings where the age of the subject is given, or where there is a likelihood of the drawing reproducing the original specimen with faithfulness. For instance, if, in illustrations, we compare the position of the inner part of the transverse palatine suture with the teeth, we find its relations given opposite certain teeth as follows:—

Age.	Position.	Reference.
1. Fœtus, 4–5 months	Posterior border of 2nd milk molar	Quain, *Osteology*, p. 77.
2. Fœtus, 9 months .	Middle of 2nd milk molar	Tomes, *Dental Anatomy*, 6th ed., p. 223.
3. "At birth" . .	One-third along 2nd milk molar	Gray, *Anatomy*, 12th ed., p. 164.
4. "At birth" . .	Middle of 2nd milk molar	Morris, *Anatomy*, p. 103.
5. 13 months . .	Between 2nd milk molar and 1st molar	Tomes, *Dental Surgery*, 5th ed., p. 10.
6. 5 years . . .	Middle of 1st molar	Morris, *Anatomy*, p. 78.
7. 6 years . . .	Middle of 1st molar	Tomes, *Dental Anatomy*, p. 239.
8. 6 years 5 months .	Two-thirds along 1st molar	Tomes, *Dental Surgery*, p. 31.
9. 7 years . . .	Posterior border of 1st molar	Tomes, *Dental Surgery*, p. 38.
10. 7 years 8 months .	Posterior border of 1st molar	Tomes, *Dental Surgery*, p. 40.
11. 15 years. . .	Anterior border of 1st molar	Tomes, *Dental Surgery*, p. 104.
12. About 20 years .	Middle of 2nd molar	Quain, *Osteology*, p. 67.
13. Adult . . .	Middle of 2nd molar	Gray, *Anatomy*, p. 183; Morris, *Anatomy*, p. 80, 81.
14. Adult . . .	Middle of 2nd molar	Cloquet, *Anatomie*, pl. xii. fig. 4.
15. Adult . . .	Middle of 2nd molar	Macalister, *Anatomy*, p. 209.
16. Adult . . .	Posterior border of 2nd molar	Cloquet, *Anatomie*, pl. ix. fig. 4.
17. Adult . . .	Anterior border of 3rd molar	Holden, *Osteology*, pl. xx.
18. Adult . . .	Middle of 3rd molar	Holden, *Osteology*, pl. xxi.

These ages in months and years are probably given from statements of the known age, not from inferences drawn from the stage of eruption of teeth.

If we disregard No 11, which may be exceptional, we see that there is a gradual regression of the suture. One can say little about the rate, whether it is constant or is variable, corresponding with the spasmodic eruptions of the teeth. Again, the position of this part of the suture with reference to the teeth may not be the best method of gauging the rate of growth of the upper jaw in the region of the alveolar border; for it has to be noted that the outer limb, before turning backwards, shows great variation in the angle it makes with the inner part. Other "data points" in the jaw or on the skull might give better results.

The relation of the two parts of the intermaxillary suture at different ages attracts notice. In the three photographs the indices obtained by multiplying the length of the posterior part by 100 and dividing the product by the length of the anterior part are 40·4, 47·8, and 33·7 for ages of 5 years, 7 years, and 11 years respectively.

But it would require access to an odontological museum, which is impossible here, before one could make authoritative statements on this and kindred subjects. Further, it would be well to have accurate information regarding the age at which the teeth erupt in aboriginals. I think it would be advisable to initiate a series of observations on this subject.

NOTE ON A TENDON FOUND IN ASSOCIATION WITH THE INSERTION OF THE PERONEUS LONGUS AND ORIGIN OF THE FIRST DORSAL INTEROSSEOUS MUSCLES.

By Lieut.-Col. J. C. LAMONT, I.M.S., *Professor of Anatomy, Medical College, Lahore.*

THE structure under record is derived from the tendon of insertion of the peroneus longus muscle as the latter is lying in its fibro-osseous tunnel in the sole of the foot. It pierces the fibrous wall of the tunnel and proceeds to the inner side of the base of the second metatarsal bone internal to the communicating branch from the arteria dorsalis pedis to the plantar arch. Traced forwards, it is found to expand into a muscular slip which becomes intimately blended with the first dorsal interosseous muscle.

The tendon appears to be a constant structure, and has been regularly demonstrated in the Lahore dissecting-room for some years past. It was thought at first that it was peculiar to the Oriental, but its presence in the European has now also been proved. In the Oriental the tendon may reach in thickness the girth of an average "digastric" tendon, but it is generally finer. In the European it appears to be smaller than in the Oriental, although here also quite easy to demonstrate.

To display the tendon the adductor obliquus hallucis should be carefully reflected from its origin and the sheath of the peroneus longus opened in its entire length. On raising and examining the inner end of the tendon of the peroneus longus, the little tendon in question can be found and followed on to the destination already described.

The arrangement described gives the peroneus longus a forceps action, and the increase in size of the tendon in the Oriental is probably due to use, as it is doubtless brought into play in grasping objects in the cleft between the first and second toes, an accomplishment possessed by many Orientals—and particularly certain oriental craftsmen such as carpenters and shoemakers—to a very remarkable extent.

I may add that in the Oriental the first dorsal interosseous muscle is generally very well developed and appears to consist of two parts, a dorsal and a plantar, and the muscular slip in association with the peroneus longus joins the dorsal part.

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DESCRIPTION OF A HUMAN EMBRYO OF 13–14 MESODERMIC SOMITES.

By ALEXANDER LOW, M.A., M.B., C.M., *Senior Assistant to the Professor of Anatomy and Lecturer on Embryology, University of Aberdeen.* (*From the Anatomy Department, University of Aberdeen.*)

THE human embryo Pfannenstiel III. was placed at the disposal of Professor Keibel, for publication in his *Normentafel zur Entwickelungsgeschichte des Menschen*, by Professor Pfannenstiel of Griefswald. In the *Normentafel* the embryo is No. 6 (fig. Vr. and Vv.) Professor Keibel kindly afforded me the opportunity of studying this embryo in the Anatomical Institute in Freiburg, and at his suggestion I undertook to reconstruct models of the embryo according to Born's method. The work of modelling was begun in the Anatomical Institute in Freiburg, and completed in the Anatomy Department, Aberdeen University.

The embryo Pfannenstiel III. was obtained at an operation, and as measured through the amnion had a length of 2·6 mm. The embryo was fixed in formalin—Muller's fluid, stained in paracarmine, and sectioned at a thickness of 10μ. Histologically the embryo is in an excellent state of preservation. A model of the whole embryo has been reconstructed at an enlargement of 100. A separate model of the nervous and alimentary systems has also been made, and three models of pharynx, heart with its blood-vessels, and septum transversum at an enlargement of 150.

EXTERNAL FORM. (Plates I. and II.)

The embryo is somewhat similar to the embryo von Bulle of Kollmann (7), which shows fourteen mesodermic somites and measured 2·5 mm. in length, but is not so far developed; indeed, its outer form more nearly approaches

that of the embryo of eight paired somites and a length of 2·11 mm. described and modelled by Professor Eternod (4). Like the Eternod embryo, it is spirally twisted in its long axis, and shows the same three back curvatures —a convex neck bend, a concave dorsal, and a convex rump. The dorsal flexure is slight, while the neck bend makes a right angle with the body, approaching in this respect the form of the embryo of twenty-three somites and a length of 2·15 mm. described by Professor Peter Thompson (9). The medullary plate is still open at its head and caudal ends. The front of the head is directed down and slightly to the right over the bulging heart region, and thus is formed a well-developed stomodæum. Three visceral clefts are visible—the first and second being deep, the third a shallow groove. The first and second visceral clefts lie dorsal to the rounded swelling caused by the commencing mandibular arch. The first cleft occupies a position more to the cranial end of the embryo. The second cleft is separated by a convex ridge from the first, and its caudal end extends to the convexity of the body wall caused by the heart. The third visceral cleft is caudal and somewhat more dorsal, and separated by a considerable interval from the other two clefts. Its ventral end leads into a depression of the body wall behind the pericardial region. The ear pit is represented by an oval depressed area of thickened epithelium just cranial to the dorsal end of the third visceral cleft. There is a large elongated umbilical opening through which the embryonic and extra-embryonic cœlom are in communication. The yolk sac is constricted at its communication with the primitive intestine to form a distinct neck. The body stalk arises from the ventral aspect of the embryo and passes to the right, lying first in front and then to the right of the caudal end of the embryo, the tail being directed to the left. The body stalk is separated from the neck of the yolk sac by a narrow interval. The caudal end of the embryo is swollen out, and terminates in a blunt point; a trace of the primitive streak is prolonged from the medullary groove to the cloacal membrane. Along the line of attachment of the amnion to the lateral body wall on each side there is a ridge caused by the underlying umbilical vein; this ridge bounds the umbilical orifice laterally. The amnion extends on to the dorsal aspect of the body stalk, leaving its lateral and ventral aspects uncovered—a disposition similar to that in the embryo described by Professor Thompson.

Mesodermic Somites and Notochord.

There are thirteen pairs of well-formed mesodermic somites, and in addition to these there is an anterior pair incompletely formed. This most anterior and rudimentary pair of somites is situated just at the level of

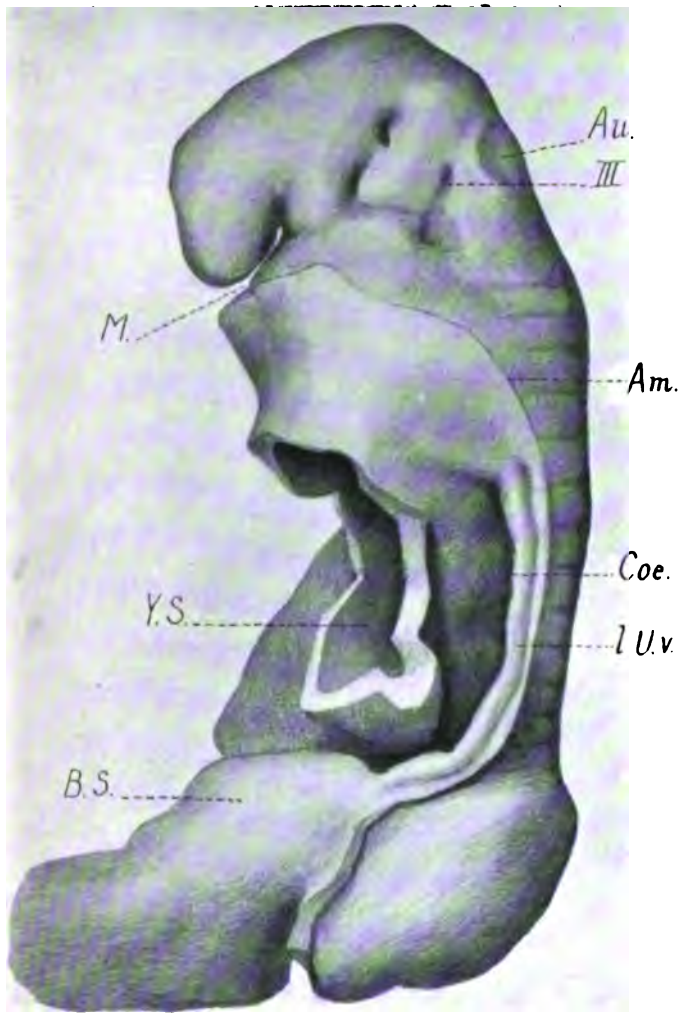


PLATE I.

the neck bend. The last pair of somites are well formed, and situated at the level of the commencement of the rump bend. As the ganglia are not developed, it is not possible to differentiate the regions to which the somites belong. Each somite has a uniformly thick wall three or four cells deep, enclosing a distinct cavity (myocœl). Towards the cavity many of the cells are undergoing mitotic division. The more cranial-placed somites are triangular on cross-section, while the more posterior ones are quadrangular (fig. 1). The notochord extends from a point behind the buccopharyngeal membrane, to end in the caudal region just short of the hind-

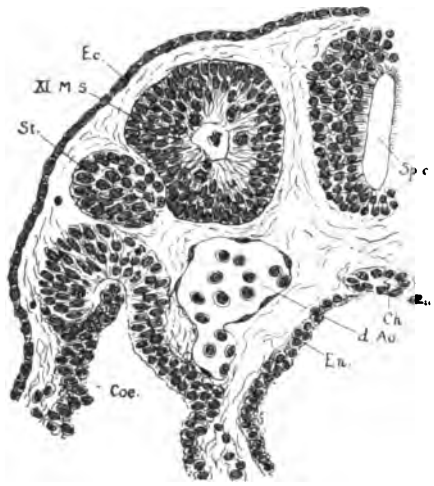


FIG. 1.—Right half of a transverse section of the embryo through the region of the eleventh mesodermic somite.

Ec., ectoderm; *XI.M.S.*, mesodermic somite; *St.*, segmental tubule; *Cœ.*, cœlom; *d.Ao.*, dorsal aorta; *Sp.c.*, medullary canal; *En.*, entoderm; *Ch.*, notochord.

gut and between the cloaca and medullary plate, and not extending into the tail. The chorda lies in close relation with entoderm forming the roof of the intestine, and only toward its caudal termination is it quite separated off, and here lies in the mesoderm midway between the gut and the medullary plate. At its cranial commencement the chorda is at first not separated off, but appears more as a heaping up of entoderm cells in the roof of the pharynx; soon, however, it becomes more differentiated, as represented in fig. 2. At the level of the first pair of mesodermic somites the chorda appears more as an evagination of the entoderm of the root of the gut, and this condition obtains almost to its caudal end, where it gets

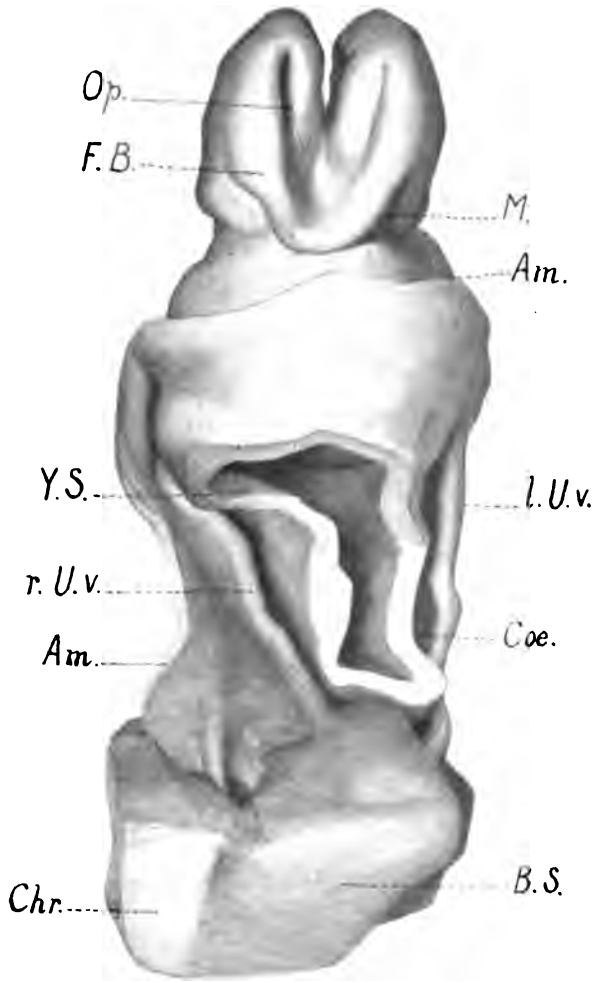


PLATE II.

quite separated off from entoderm (fig. 3). The cells of the chorda are large, oval, and clear, and contain small, distinctly staining nuclei; in some of the cells mitosis is seen. There is no trace of a cuticular membrane.

Vascular System.

Cardinal Veins.—The anterior cardinal veins, containing blood-cells, are present in the region of the first to the fifth mesodermic somites. A connection with the heart cannot be established from a careful examination of the sections. No trace of posterior cardinal veins is to be seen.

Vitelline Veins.—Although in the wall of the yolk sac are numerous blood-vessels containing blood-cells, still the vitelline veins are difficult to trace. Their terminal parts can be defined where they lie in the septum transversum on the ventral aspect of the gut, and open into the sinus venosus mesial to the umbilical veins. Before they open into the sinus venosus, a transverse piece connects the two vitelline veins.



Fig. 2.—Notochord in region of first pair of mesodermic somites, and Fig. 3 in caudal region.

En., entoderm of gut; *Ch.*, notochord; *Sp.c.*, spinal cord; *Ao.*, dorsal aorta.

Umbilical Veins.—The umbilical veins are large vessels, and lie in the body stalk at first dorsal to the umbilical arteries; here they communicate, and then run cranialwards in the body stalk to gain the lateral body wall. From the lateral body wall the cranial end of each vein bends abruptly, passing mesially and ventrally each to join its own horn of the sinus venosus; here each vein lies embedded in the septum transversum and close to the floor of the parietal recess (fig. 12).

Aortæ.—The aortic stem divides into a pair of aortic arch vessels, which pass on either side of the median thyroid anlage backwards in the first visceral arch, and each of these is continued caudally as a dorsal aorta. There are traces also of a second pair of aortic arch vessels. The dorsal aortæ rest on the roof of the gut on either side of the notochord, and do not unite in any part of their course, remaining paired throughout and terminating on the sides of the cloaca. A short distance before the termination of the dorsal aortæ the umbilical arteries are given off and

pass on either side of the allantoic duct into the body stalk, where they unite, forming a single trunk, which again divides into two vessels.



FIG. 4.

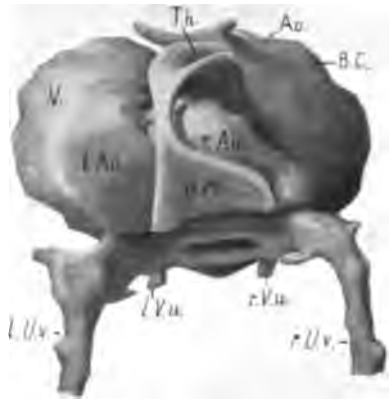


FIG. 5.

Model of heart. × 75. Fig. 4, viewed from the front and left; fig. 5, seen from behind.

Ao., aortic stem; *B.C.*, bulbus cordis; *V.*, ventricle; *r.Au.*, right auricle; *l.Au.*, left auricle; *s.v.*, sinus venosus; *r.U.v.*, right umbilical vein; *l.U.v.*, left umbilical vein; *r.V.u.*, right vitelline vein; *l.V.u.*, left vitelline vein; *D.M.*, dorsal mesentery; *Th.*, depression in mesentery into which median thyroid extends.

The Heart.—The heart is in a stage very similar to that represented by Born's model (1) of the heart of a rabbit embryo of 0·95 mm. length—model 1 (Ziegler). The heart as a whole is **S**-shaped, and shows sinus

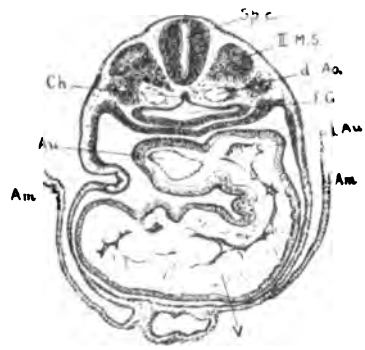


FIG. 6.—Transverse section in region of second pair of somites. × 50.

Am., amnion; *Au.*, auricle; *V.*, ventricle; *Sp.c.*, medullary canal; *Ch.*, notochord; *II. M.S.*, second somite; *d.Ao.*, dorsal aorta; *F.G.*, fore-gut.

venosus, auricle, ventricle, and just at the base of the aortic stem a slight dilatation which may represent a bulbus cordis.

The sinus venosus is crescentic in shape, with dilated ends, and is

situated in the septum transversum in close relation with the ventral wall of the gut. Opening into its horns are the terminations of the large umbilical veins, and mesial to these the vitelline veins. The sinus passes into the auricle without any very distinct constriction except on the left side, where there is a slight furrow between the two.

The auricle lies dorsal to the ventricle. Its transverse diameter is the greater, and it is divisible into a smaller right part and a larger left by a distinct in-pushing—the dorsal mesentery being attached here. The left part of the auricle is separated from the ventricle by a slight groove.

The ventricle is U-shaped, with the left limb much the larger and

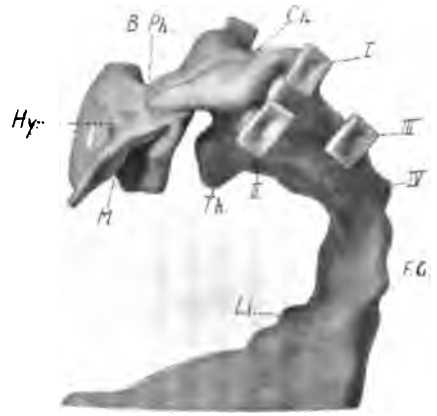


FIG. 7.—Model of pharynx. × 75. Seen from the left side and slightly from the front.

M., mouth; *Hy.*, hypophysis; *B.Ph.*, bucco-pharyngeal membrane; *Ch.*, notochord; *I.-III.*, visceral clefts; *IV.*, fourth pharyngeal pocket; *Th.*, median thyroid; *F.G.*, fore gut; *Li.*, liver bay.

passing dorsally and to the left to open into the left side of the auricle. The cranial end of the right limb becomes constricted, and then is succeeded by a somewhat dilated part, which may indicate the bulbus cordis which is so largely developed in the embryo described by Professor Thompson.

ALIMENTARY SYSTEM.

The mouth is represented as a narrow transverse fissure between the fore brain and the body wall. In its roof is a slight funnel-shaped out-pushing—the commencement of the pocket of ectoderm to form the hypophysis. The mouth is separated from the pharynx by a complete bucco-pharyngeal membrane. The pharynx widens out rapidly behind this, and is flattened dorso-ventrally (fig. 7). There are four pairs of pharyngeal

pouches, of which the third and fourth are small and pointed. The second pocket is so situated that it lies much more ventral than caudal to the first pocket. The first two pairs of pockets are elongated vertically, and come in direct contact with the external ectoderm, where it forms the bottoms of the first and second pairs of visceral clefts (fig. 7). The third and fourth pockets do not come in contact with the ectoderm. In the floor of the pharynx in the region of the second pockets is present the median thyroid anlage as a relatively large, widely open, funnel-shaped cavity with its apex passing caudally between the aortic arches (fig. 8). The lung anlage is not plainly indicated, but caudal to the median thyroid is a groove in the entoderm which may indicate the lung groove. As the fore-gut is traced

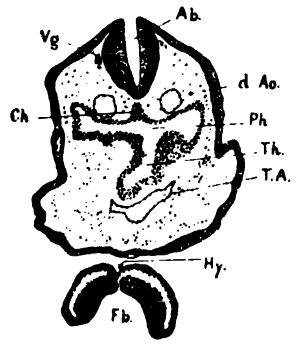


FIG. 8.—Section through region of hind-brain. × 50.

Fb., fore-brain; *Ab.*, hind-brain; *Hy.*, hypophysis; *Ch.*, notochord; *Vg.*, vagus ganglion; *d.Ao.*, dorsal aorta; *Ph.*, pharynx; *T.A.*, aortic stem; *Th.*, median thyroid.

towards the yolk sac, its lumen becomes narrowed transversely and elongated dorso-ventrally; and just before it opens out into the yolk sac, there is a liver bay with walls of thickened entoderm. There is no actual liver bud and no trace of liver trabeculæ. The middle third of the alimentary tract is still in communication with the yolk sac. The hind gut is narrowed at a point opposite the attachment of the body stalk, and then dilates to form a large cloaca. Dorsally the cloaca is expanded with convex walls, while ventrally it is narrowed so that its cavity forms a fissure. Ventrally the entoderm of this anterior fissure-like part of cloaca is in direct contact with the ectoderm, forming an elongated cloacal membrane. Cranial to the cloacal membrane the cavity of the cloaca leads into the small lumen of the allantois. The allantoic duct passes into the body stalk between the two umbilical arteries, which eventually surround it by anastomosing across it. There is a very small post-anal gut pro-

jecting caudally between the posterior limit of the cloacal membrane and the tip of the notochord.

Excretory System.

The excretory system is in a very early stage of development. Professor Felix of Zurich is to describe this in detail in a separate paper on the development of the excretory system in early human embryos. I may say that this embryo shows rudimentary pronephric tubules in the region of the eighth, ninth, and tenth mesodermic somites, and segmental vesicles

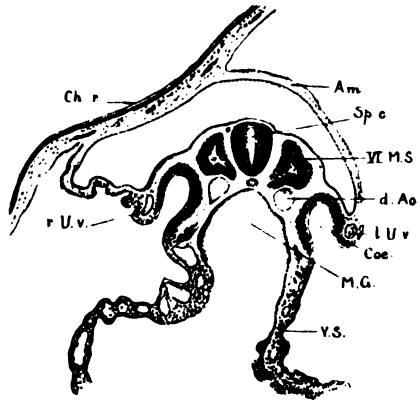


Fig. 9.—Section through region of sixth somite. × 50.

Am., amnion; *Sp.c.*, medullary canal; *VI. M.S.*, sixth somite; *d.Ao.*, dorsal aorta; *l.U.v.*, left umbilical vein; *Cœ.*, cœlom; *M.G.*, mid-gut; *Y.S.*, yolk sac; *r.U.v.*, right umbilical vein; *Chr.*, chorion.

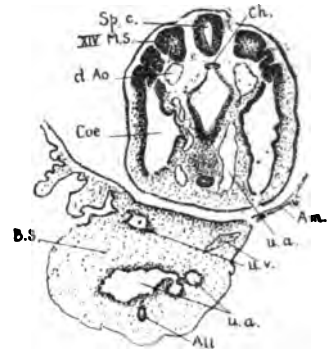


Fig. 10.—Section through region of hind-gut. × 50.

Sp.c., medullary canal; *Ch.* notochord; *Am.*, amnion; *U.a.*, umbilical artery; *U.v.*, umbilical veins; *All.*, allantoic duct; *B.S.*, body stalk; *Cœ.*, cœlom; *d.Ao.*, dorsal aorta; *XIV. M.S.*, fourteenth somite.

in connection with the eleventh, twelfth and thirteenth segments. There is no Wolffian duct.

Cœlom and Septum Transversum.

All parts of the cœlom are in communication with each other. The pericardial cœlom is very large, and extends cranially on either side of the median thyroid anlage. Ventrally the pericardial cœlom causes a bulging of the body wall, the ventricle lying in close apposition with it; while dorsally it is prolonged round into the parietal recesses of His (5). Figs. 11 and 12, from a model, show the relation of the umbilical vein and sinus venosus to the floor of the parietal recess, as also the two horn-like extensions of the septum transversum described by Professor Thompson (10). On the right

side there is an infolding of the body wall which produces a ridge running from the anterior part of the dorsal mesocardium to the septum transversum, and slightly constricting off the pericardial cœlom from the parietal

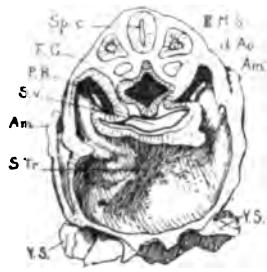


FIG. 11.

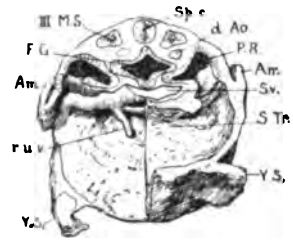


FIG. 12.

Model showing septum transversum viewed from above. Fig. 12 shows right half of septum removed and the right umbilical vein passing in to open into the sinus venosus.

Sp.c., medullary canal: *d.Ao.*, dorsal aorta; *P.R.*, parietal recess; *Am.*, amnion; *S.v.*, sinus venosus; *S.Tr.*, septum transversum; *Y.S.*, yolk sac; *r.u.v.*, right vitelline vein; *F.G.*, fore-gut; *III.*, third somite.

recess; this may be the "pulmonary ridge" of Mall (8). Only the cranial end of this ridge is present on the left side.

NERVOUS SYSTEM.

The medullary plate is open at its head and tail ends almost to the same extent as in Eternod's embryo of eight mesodermic somites. In

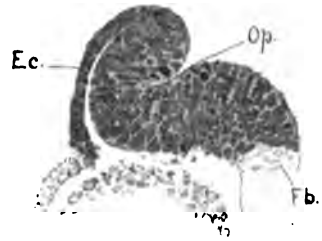


FIG. 13.—Section through optic vesicle (*Op.*).
Fb., wall of fore-brain; *Ec.*, external ectoderm.

Kollmann's embryo of fourteen somites the medullary groove is closed behind, but open anteriorly. The brain shows very distinctly the three parts, prosencephalon, mesencephalon, and rhombencephalon, separated by grooves (Plate III.). There is no demarcation between the rhombencephalon and the spinal cord, but the junction seems to be at the neck bend at the

level of the first pair of mesodermic somites. Just cranial to this point the two folds of the medullary groove have fused. The fore-brain shows elongated, gutter-like evaginations of its later walls which are the commencing optic vesicles. The walls of these vesicles are many cells thick, and are in close contact with the external ectoderm (fig. 13). From the floor of the fore-brain is a slight out-pushing, the anlage of the infundibulum. The mid-brain is bounded in front and behind by grooves, and its transverse diameter is rather less than that of either fore-brain or hind-brain. The hind-brain forms by far the largest part of the whole brain, and passes without distinct demarcation into the spinal part of the medullary tube. The hind-brain is of interest in that it shows certain

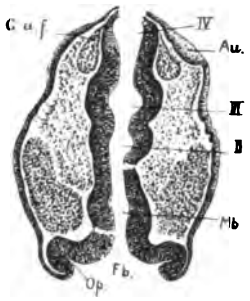


FIG. 14.—Section through head of embryo. × 50.

Fb., fore-brain; *Mb.*, mid-brain; *II.*, *III.* and *IV.*, 2nd, 3rd and 4th neuromeres of hind-brain; *Op.*, optic vesicle; *Au.*, auditory pit; *G.a.f.*, ganglion acustico-facialis.

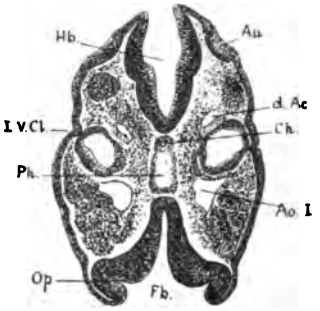


FIG. 15.—Section through region of first visceral cleft. × 50.

Fb., fore-brain; *Hb.*, hind-brain; *Op.*, optic vesicle; *Ph.*, pharynx; *I.V.Cl.*, first visceral cleft; *Au.*, auditory pit; *d.Ao.*, dorsal aorta; *Ch.*, notochord; *Ao.I.*, first aortic arch vessel.

neuromeres very clearly; these neuromeres form folds involving the whole thickness of the lateral wall of the hind-brain, and are convex externally, with corresponding concavities internally (fig. 14). The neuromeres are seven in number, as has already been noted by Broman (3) in a human embryo of 3 mm., and more recently by Thompson in the twenty-three somite embryo and Ingalls in an embryo of 4·9 mm. (6). The first neuromere is the smallest, and does not reach the ventral margin of the brain, while the second neuromere is the largest and best defined. The third neuromere is also prominent, but not so wide as the second, and its ventral end tapers off to a point between the ventral ends of the second and fourth neuromeres. The fourth neuromere is pointed dorsally and widens out below, between its ventral end and that of the second neuromere being a notch as described by Bremer (2) in a 4 mm. embryo. The ganglion acustico-facialis is attached to the upper end

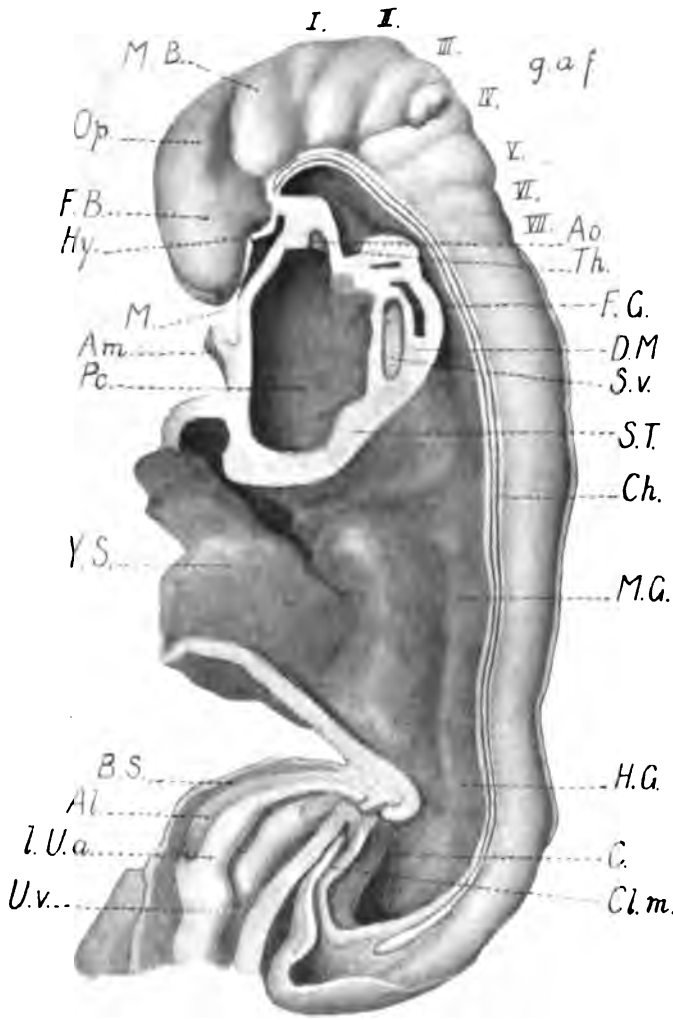

I.
I.
M.B.
III.
g.a f
IV.
Op.
V.
VI.
F.B.
VII.
Ao
Hy.
Th.
F.G.
M.
Am.
D.M
Pc.
S.v.
S.T.
Ch.
Y.S.
M.G.
B.S.
H.G.
Al.
l.U.a.
C.
U.v.
Cl.m.

PLATE III.

of this neuromere, but largely lies in the furrow between the third and fourth neuromeres. The fifth, sixth, and seventh are not so clearly marked off.

The oval auditory field of thickened ectoderm lies over the dorsal end of the fifth neuromere, but also extends over the upper end of the fourth. The trigeminal ganglion is not developed. The ganglion acustico-facialis is large, and is attached to the lateral wall of the hind-brain in connection with the anterior margin of the fourth neuromere. The ganglion of the vagus is only being developed.

The flexures of the brain agree very closely with the flexures described by Professor Thompson as being present in his embryo of twenty-three somites. There is a prominent flexure in the region between the mid-brain and hind-brain, the mid-brain and fore-brain being bent downward. The anterior extremity of the notochord is bent down in a corresponding manner. There is also a distinct flexure of the hind-brain at the notch between the ventral ends of the second and fourth neuromeres. The neck flexure is just commencing, and forms an open angle (Plate III.).

In conclusion, I wish to express my thanks to Professor Wiedersheim for kindly granting me permission to work in his laboratory; more especially to Professor Keibel for the loan of the embryo, and much help and advice; and also to Professor Pfannenstiel to whom the embryo belongs. I also express my indebtedness to Professor Reid in connection with my research work, and to the Carnegie Trustees for a grant toward the cost of embryological research and the illustration of this paper.

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EXPLANATION OF PLATES.

Plate I. Model of the embryo, left side (enlarged 60 times).

Plate II. Model of the embryo, frontal view (enlarged 60 times).

Plate III. The same model in sagittal section, viewed from the left.

Al., allantoic duct; *Am.*, amnion; *Ao.*, origin of first aortic arch; *B.S.*, body stalk; *Ch.*, chorda dorsalis; *Chr.*, chorion; *Cl.*, cloaca; *Cœ.*, cœlom; *D.M.*, dorsal mesentery; *F.B.*, fore-brain; *F.G.*, fore-gut; *G.a.f.*, ganglion acustico-facialis; *H.G.*, hind-gut; *Hy.*, hypophysis; *M.*, mouth; *M.B.*, mid-brain; *M.G.*, mid-gut; *Op.*, optic vesicle; *Ot.*, otic pit; *P.C.*, pericardial cœlom; *S.T.*, septum transversum; *S.v.*, sinus venosus; *Th.*, median thyroid; *l.U.a.*, left umbilical artery; *l.U.v.*, left umbilical vein; *r.U.v.*, right umbilical vein; *Y.S.*, yolk sac; *I. and III.*, first and third visceral clefts; I.–VII., first to seventh neuromeres.

STUDIES IN THE ANATOMY OF THE PELVIS, WITH SPECIAL REFERENCE TO THE FASCIÆ AND VISCERAL SUPPORTS.

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PART II.

THE RECTO-VESICAL SEPTUM.

IF, in the dissection of the pelvis, one attempts to tear the peritoneum away from the subperitoneal tissues, it will be found to be firmly attached at the bottom of the recto-vesical recess to a very thick, strong membrane, which Denonvilliers described seventy years ago (15) and called the "prostato-peritoneal aponeurosis." As this expression is somewhat cumbrous for general use, I shall refer to it as the "recto-vesical septum." It consists of a very thick posterior layer, which is separated from the rectum by a narrow cleft (fig. 9, D; fig. 10, PRERECTAL SPACE) filled with fat; and a much thinner anterior layer (fig. 10, B) in contact with the vesiculæ seminales, vasa deferentia, and the back of the prostate. Both layers become fixed to the upper posterior corner of the prostate (opposite the line D, fig. 9); below that they become separable, and the potential space between these two layers is the "espace décollable rétro-prostatique" of Proust (see Delbet, fig. 107 *bis*, p. 163). In his operation for perineal prostatectomy Proust cuts through the perineal body (the recto-urethral muscle) and then opens this recto-prostatic space; the rectum can then be pulled back and the whole prostate exposed in the wide, gaping chasm thus revealed (see Deaver, 8, pp. 232 *et seq.*; and Young, 16, p. 18). If it be desired merely to free the rectum, this can be done more completely by cutting through the superior recto-urethral muscle and opening the prerectal space.

A third layer of membrane passes downward from the anterior wall of the recto-vesical recess to the interval between the bladder and vesiculæ seminales (fig. 9). The connective tissue around the vesiculæ seminales and the vasa deferentia becomes condensed and attached to the second and third of these sheets of aponeurosis: in this way the capsules of the organs are formed.

Cunéo and Veau (17, p. 242; see also Fredet, 5, pp. 1042 and 1043)

have shown that all three layers of the aponeuroses of Denonvilliers are derived from peritoneal folds. I have studied the development of the prostato-peritoneal aponeurosis in human embryos and have been able to confirm the work of Cunéo and Veau. In a mesial section through the pelvis of a male fœtus of the fourth month (fig. 11) the recto-vesical recess of the peritoneum is seen to be very much deeper than it is in the adult; it extends downward on to the posterior aspect of the prostate and is attached there to the upper extremity of the perineal body—(see also Keibel's figure, Eberth (6, p. 296) and Keith's diagram (14, p. 139)).

The two layers of this peritoneal recess become loosely attached one to the other and their serous covering disappears, the two layers of peritoneum becoming transformed into or replaced by a double sheet of fibrous tissue, mixed with some unstriped muscle. The extent of this part of the peritoneal recess, which becomes obliterated, is shown diagrammatically in fig. 10 (A and B are the two layers). The two leaves of the recto-vesical septum are in contact the one with the other and are only loosely attached except at the upper edge of the prostate (fig. 10, PR.); if the thick posterior layer (A) is pulled backward, it seems to be fixed to the prostate at this point. Yet it does not require much force to separate the two sheets even at this point. The cleft that is made by thus pulling asunder the two layers is the "retro-prostatic space" of Proust.

The lateral borders of the recto-vesical septum are not fixed to the lateral pelvic walls. If this septum be followed in a coronal section (fig. 3), as it passes away from the mesial plane, its fibres will be found to scatter in the mass of connective tissue packed around the vesiculæ seminales, vesical veins (PLEX. VEN. VESICAL), and nerves (PLEX. NERV. VESICAL); and none of these fibres (or very few of them) reach the lateral wall of the pelvis, *i.e.* the aponeurosis of the ilio-coccygeus muscle. The position of the recto-vesical septum is indicated in fig. 15; the position of its lateral edge is indicated by the letters F and D in fig. 13, the mass A E D being the connective tissue surrounding the vesical plexuses (veins and nerves), to the inner aspect of which Denonvilliers' aponeurosis may be said to be attached. Testut (18, fig. 605, p. 717; fig. 631, p. 746; fig. 657, p. 775) gives some excellent illustrations of this septum.

The recto-vesical septum is practically identical with the recto-vesical layer of the visceral pelvic fascia, as described by Cunningham (19, p. 515): but I have avoided the use of the term recto-vesical fascia, partly because this expression is being used by other writers as a synonym for "visceral pelvic fascia," but also because I want to emphasise the fact that the borders of the structure that I have called recto-vesical septum are not

connected with surrounding structures in the way those of Cunningham's recto-vesical layer are said to be fixed. The superior border is attached to the peritoneum, and does not pass up on to the superior surface of the bladder (compare fig. 9, and Cunningham's fig. 176, p. 517). The lateral borders are either quite free or attached to the mesodermal sheath of the vesical plexuses (fig. 3), whereas the "recto-vesical layer" is one of three sheets formed by the splitting of the visceral pelvic fascia (the inner aponeurosis of the levator ani) which "springs from the inner surface of the parietal pelvic fascia (also the inner aponeurosis of the levator ani or the muscle itself transformed into fibrous tissue) along the *white line*" (compare fig. 9 with Cunningham's fig. 174 and fig. 175). The inferior border of the recto-vesical septum is attached to the perineal body, which forms the lower part of the septum between the rectum and the urogenital organs—the prerectal raphé (Charpy).

The best way to study the recto-vesical septum is to take a pelvis, cut through the peritoneum on the rectal side of the recto-vesical recess, and pull the rectum backward (or, better still, cut the rectum away by snipping through the walls of the rectal ampulla). In this way a great triangular sheet of white tissue will be exposed: its three angles are placed respectively at the outer extremities of the vesiculæ seminales and the lower edge of the prostate. At its lateral edges the handle of a knife can easily be pushed forward between it and the pelvic wall. The practical importance of this fact is shown by the readiness with which pathological processes can spread from the neighbourhood of the bladder toward the rectum, or *vice versa*, past the lateral borders of Denonvillier's aponeurosis. Diverticula developed from either organ (when its walls are weakened by some such process as Bilharziosis) push their way from the vesical to the rectal compartment, or *vice versa*, with the greatest ease.

In studying the anatomy of this region as it is affected by pathological conditions, I met with a surprising illustration of the error into which one might fall in attempting to predict the spread of a disease by the mere application of anatomical knowledge. If there is any fascia in this region which is stronger than another, it is that central part of the posterior layer of the aponeurosis of Denonvilliers that is interposed between the rectum and the vesiculæ seminales (and vasa deferentia). It might be thought that in case of disease of the vesiculæ the line of resistance in the direction of the bladder would be so much weaker than that toward the rectum that the spread of disease would always be bladderward, but I have recently dissected the pelvis in a case of advanced tuberculosis of the vasa deferentia and vesiculæ seminales

in which the prostato-peritoneal aponeurosis had been perforated at its centre and an opening formed into the rectum, while the bladder was spared. (Of course the mere mechanical circumstances are not of paramount importance in determining the course of a tubercular ulceration; nevertheless, this example is surprising.)

The Capsule of the Prostate.[1]

I have already referred to the fact that, in most of the subjects examined in the course of this investigation, the dorsal vein of the penis poured its blood directly into one or both internal pudic veins. At the same time it communicates with (and in some cases discharges most or even all of its contents into) the pudendal plexus, which is commonly called the "prostatic plexus" (in the male) in English text-books (the "plexus of Santorini" by French writers). This plexus, however, has little claim to the name "prostatic" beyond its topographical relations; it is really a bond of union between three systems of veins: the dorsal vein of the penis (or clitoris), the internal pudic veins, bringing blood from the perineal and anal regions and the vesical veins. The valves in the plexus are so arranged that blood can escape from it only by the vesical veins (fig. 7). It almost always happens that there is some communication between the pudendal plexus (or one of its afferent or efferent trunks) and the obturator vein. It may be the vesical part (fig. 7) or it may be the commencement of the internal pudic (fig. 6) that is joined to the obturator, either within (fig. 7) or outside the pelvis (on the outer surface of the obturator membrane, fig. 6—compare Rieffel's modification of Kobelt's drawing (4, p. 607)).

The very intimate connections of various branches of the pudendal plexus with the obturator vein have been admirably shown in the excellent picture, borrowed from Farabeuf, in Poirier's treatise (20, fig. 717, p. 707). It is very surprising to find such a great authority on prostatic anatomy as Deaver (8) making the statement that "no tributaries come from the parietal veins of the pelvis" (p. 32), when Farabeuf shows a perfect forest

[1] Within the last few years a very annoying element of confusion has been introduced into the literature of pelvic anatomy by certain surgeons (see, for example, the memoirs written by Deaver (8), and Thomson Walker (10)), who have attempted to revive the use of the terms "capsule" and "sheath" in reference to the prostate, as employed by Sir Henry Thompson, giving them a meaning utterly at variance with the custom of the vast majority of anatomists of all nationalities. The pretended justification of this employment of the terms—*i.e.* giving the term "capsule" the meaning associated with it in the case of such an organ as the kidney or liver—would hardly be a sufficient excuse for the flagrant introduction of so much confusion, even if it were justified; but the advocates of a consistent use of the term "capsule" cannot lay claim to even the justification of being logical, seeing that they regard as part of their "sheath" the anterior part of the capsule (the preprostatic layer of Zuckerkandl), which is strictly comparable to the "capsule" of any other viscus.

of veins on the back of the pubes, joined not only to the vesical veins, but also to the prostatic plexus. My own dissections absolutely confirm in every particular the work of Farabeuf.

The mesodermal tissue around the pudendal plexus becomes condensed

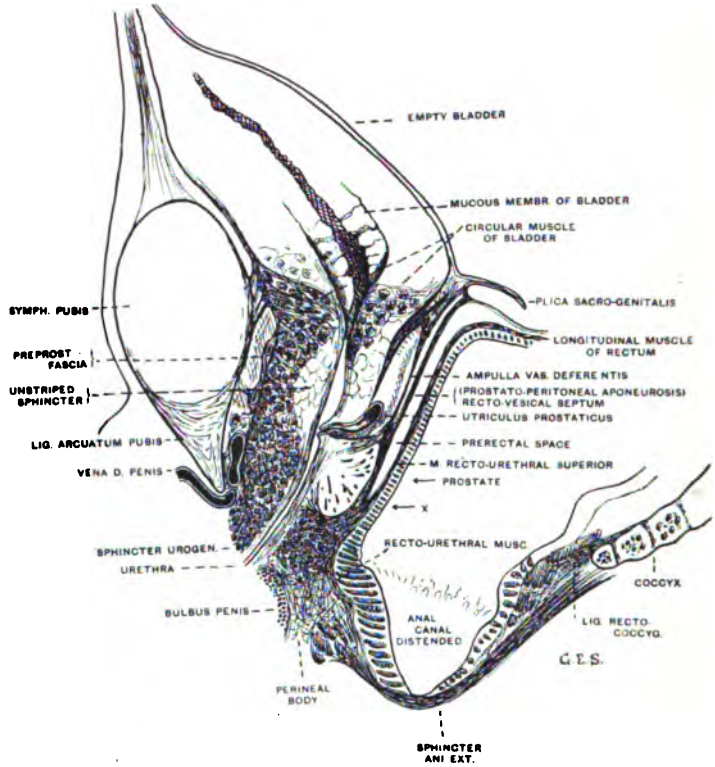


FIG. 12.—The mesial sagittal section of the pelvis of a Soudanese negro (æt. 30 ann.), showing an infantile type of bladder.

The sphincters of the bladder and urethra are shown with exceptional distinctness. Compare Kalischer's diagram in Eberth, 6, p. 192; the figures in Delbet, 2, p. 151; and Thomson Walker, 10, p. 196. X is the place where the longitudinal musculature on the anterior surface to the rectum becomes inserted into the perineal body (M. RECTO-URETHRAL. SUPERIOR).

to form a hard fibrous stroma, so that when one cuts into the upper part of the capsule of the prostate the vessels look more like sinuses such as we find in the cranial meninges than ordinary veins. This fibrous tissue, which forms the matrix of the pudendal plexus, fuses with the sheath of the sphincter urogenitalis (fig. 12). In this way is formed the anterior layer of the capsule of the prostate—the preprostatic layer of Zuckerkandl. In a mesial sagittal section (fig. 10, PREPROST. FASC.) it is seen to be con-

tinuous inferiorly with the transverse ligament of the pelvis, and superiorly is attached to the bladder, in close proximity to the pubo-prostatic ligaments.

The whole of the "prostate" which lies in front of the urethra in the section represented in fig. 12 consists of muscle. There is a thin layer of longitudinal muscle, a fusiform mass of circular unstriped muscle (UNSTRIPED SPHINCTER)—sphincter vesicæ internus[1] of Henle (lissosphincter urethræ of Waldeyer; sphincter trigonalis of Kalischer)—and in front of this the upper part of the striated sphincter (SPHINCTER UROGENITALIS; Waldeyer's rhabdosphincter urogenitalis (pars posterior): Henle's external sphincter vesicæ).

It is the sheath of this sphincter urogenitalis which unites with the matrix of the prostatic plexus to form the preprostatic fascia (fig. 12) or anterior part of the capsule of the prostate. This is the reason why the anterior (unlike the lateral and posterior) part of the capsule is attached to the prostate, as Stoney (27) and Walker (10) have pointed out.

The lateral surface of the prostate is devoid of striated muscular tissue (see Kalischer's illustration in Eberth, 6, fig. 176, p. 195). Hence there is no attachment of the matrix of the prostatic plexus (fig. 5) to the prostate, for, it will be remembered, in the last paragraph I pointed out that it is the fusion of this matrix to the sheath of the striated sphincter which leads to the fixation of the anterior part of the capsule to the prostate.

The lateral part of the capsule, on the other hand, consists of the continuation of the same supporting tissue of the veins, fused on its *outer* aspect to the inner aponeurosis of the levator ani muscle (fig. 5); and, as the latter becomes firmly fixed to the triangular ligament and perineal body (CENTR. TENDIN. PERINÆI), it follows that the capsule of the prostate has this attachment.

At the base of the prostate the venous matrix expands to enclose the large vesical veins (fig. 5), and, at the same time, it leaves the levator ani and passes on to the bladder, thus forming the lateral true ligament[2] (fig. 5, LIG. LAT. VESICÆ).

The posterior part of the capsule of the prostate is formed mainly by the recto-vesical septum or prostato-peritoneal aponeurosis of Denonvilliers

[1] My examination of a series of bladders in various stages of natural distension (fixed by intravascular injection of formalin) enables me to confirm the opinion expressed by Ball (21), that Henle's internal sphincter plays an important rôle in shutting off the bladder from communication with the urethra. This is well shown in fig. 9, where the internal sphincter is shown so tightly contracted that it has rendered oblique the part of the urethra intervening between the bladder and the verumontanum.

[2] This term is much preferable to the expression "recto-vesical fascia," used by many writers.

(figs. 9, 10, and 12); a few small veins embedded in fibrous tissue are fused to the anterior surface of the recto-vesical septum (fig. 12). Like the lateral parts, the posterior wall of the capsule is not attached to the prostate. Its attachment to the perineal body completes the capsule of the prostate below. Laterally the aponeurosis of Denonvilliers is not firmly attached to the aponeurosis of the levator ani, but there is no break in the capsule of the prostate, because the matrix of the veins (which contributes to the

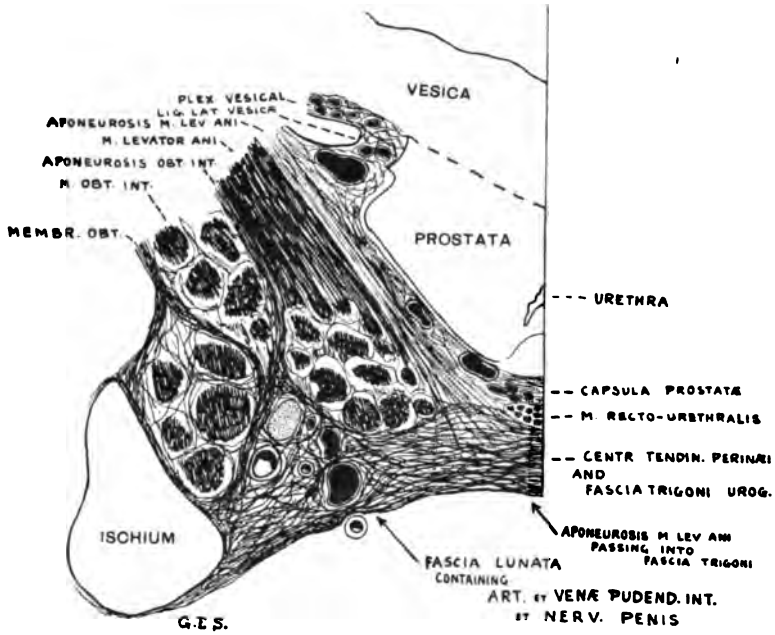


FIG. 5.—A coronal section through the left half of the prostate, base of the triangular ligament, and neighbouring structures in the plane A A (fig. 2).

This section was made in the specimen represented in fig. 2.

formation of all four parts of the capsule) secures the continuity of all parts (fig. 8, PLEXUS PUDENDALIS: the radiating lines between the pudendal plexus and the rectum represent the lowermost fibres of Denonvillier's aponeurosis).

Before we leave the consideration of the capsule of the prostate and the perineal body I wish to call attention to the great practical importance of these relations of rectum and prostate, which have just been described. This matter has been very lucidly and fully explained by Delbet (2, p. 229), so that I need add merely a short note. A glance at fig. 12 shows that in any surgical procedure to free the rectum from its anterior attachments or

to expose the whole of the posterior surface of the prostate, it is necessary to cut through the perineal body between the bulb of the penis and the external sphincter ani and then to sever the attachment of the recto-urethral muscle to the sphincter urogenitalis and base of the triangular ligament. The surgeon can then expose the back of the prostate by raising its sheath (cutting the posterior layer of the recto-vesical septum, and thus open the recto-prostatic space of Proust, fig. 10). Or, if he desires to liberate the rectum, he need not touch the aponeurosis of Denonvilliers, but merely cut through the superior recto-urethral muscle (figs. 10 and 12) and so open the prerectal space.

In the female the fibrous tissue embedding the veins on the lateral wall of the vagina is fused to the sheath of the levator ani muscle (4, p. 677), just like that on the side of the prostate; and behind the vagina we find the aponeurosis of Denonvilliers passing to the perineal body (see Delbet, 4, p. 689).

The Sacro-Vesical Cord and Pubo-Sacral Ligament.

I have just described the lateral walls of the capsule of the prostate as being the product of the fusion of an inner layer (the matrix of the veins) and an outer layer (the thickened inner aponeurosis of the levator ani muscle)—fig. 5. Neither of these elements ceases at the posterior border of the prostate; but they separate, the one from the other (fig. 13), as they proceed backward, forming two bands, which I shall call the "sacro-vesical cord" (E, D) and "pubo-sacral ligament" (F, B, C).

It is not necessary for me to describe the great mass of veins which pass backward from the region around the prostate and neck of the bladder to a point just above the ischial spine, where the large vesical vein receives the blood coming from all of these vessels and pours it into the internal iliac. There are numerous illustrations in Spalteholz's Atlas and the works quoted in the biblography (see, for example, Testut, 18, fig. 528, p. 619) which make the arrangement of these veins clear. Moreover, in fig. 13 these veins have been represented (in dotted lines in the area A, E, D) as they were exposed in a dissection. In fig. 15 the two extremities of this vascular cord (A and D) are shown.

The great mass of vesical veins, arteries, and lymphatics, which pass between the points A and D in fig. 15, is packed in fairly dense connective tissue, which is firmly attached to the sheath of each vessel and binds together the various elements in this vascular cord. The result of this is that if, in a pelvis from which the peritoneum has been removed, one attempts to tear away the areolar and fatty tissues, the strong band A D

(fig. 13) will be found to resist all attempts, short of violent tearing, to remove it, and remains as a definite ligament, fixing the base of the bladder and prostate to the back of the pelvis.

The internal iliac vessels are firmly fixed in the area of the great sciatic foramen by a dense layer of fascia, which covers them and all their branches and is intimately bound to their sheaths. Moreover, the whole group of vessels is embedded in a solid mass of connective tissue, which is placed in

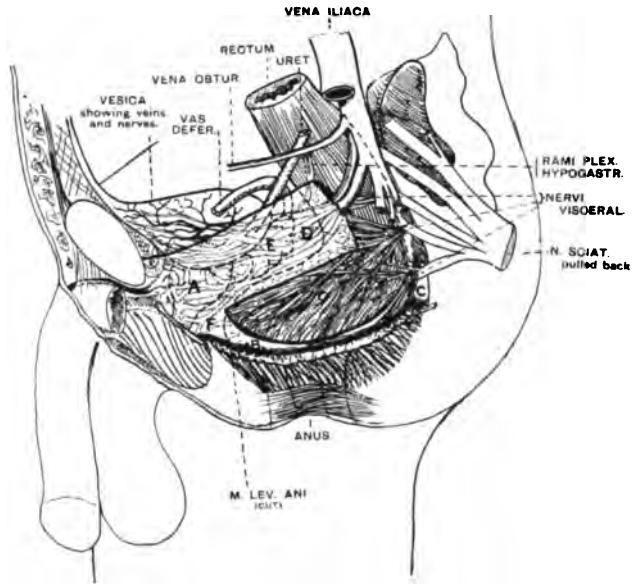


FIG. 13.—A dissection in which the left wall of the pelvis, with the obturator internus and most of the levator ani, has been removed.

A represents the position of the prostate and the lateral part of its capsule, the veins contained in it being represented by dotted lines. F represents the position of the perineal body. E represents the position of the vesiculæ seminales. F and D mark the two extremities of the lateral margin of the recto-vesical septum. G is the lateral wall of the rectum. A D is the sacro-vesical cord. A B C is the pubo-sacral ligament.

front of the sheath of the pyriformis muscle and securely bound down to the sacrum and the margins of the sciatic foramen, as well as to the sheaths of the great branches—sciatic, gluteal, and internal pudic—which are passing out of the pelvis. Thus the great vascular sheath forms a definite ligament attached in the oval space D (fig. 15) to the posterior pelvic wall.

In virtue of the intimate connection of this vascular sheath and the aponeurosis of the levator ani, in the region of the prostate (fig. 13, A), and the attachment of the latter to the pubes, it follows that the sacro-vesical cord becomes (indirectly) fixed to the pelvic wall in front.

After describing this vascular sheath, Holl adds: "Thus it comes to pass that the internal iliac vessels form a sort of septum between the

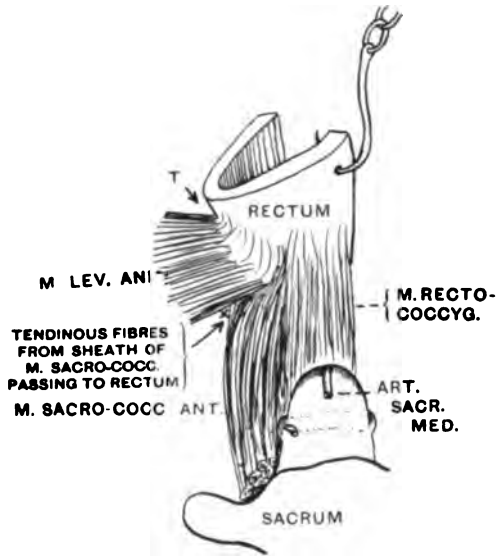


FIG. 13A.—A dissection showing the structures between the rectum and sacrum, put on the stretch by pulling forward the former.

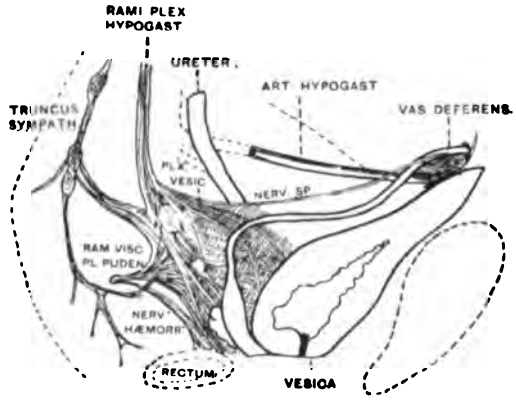


FIG. 14.

anterior and posterior parts of the pelvic cavity (perivesical and perirectal spaces)"—7, p. 294.

Below and to the inner side of the vascular sheath there is another,

much tougher and denser, element entering into the constitution of the sacro-vesical cord—it is the fibrous matrix of that complicated network of

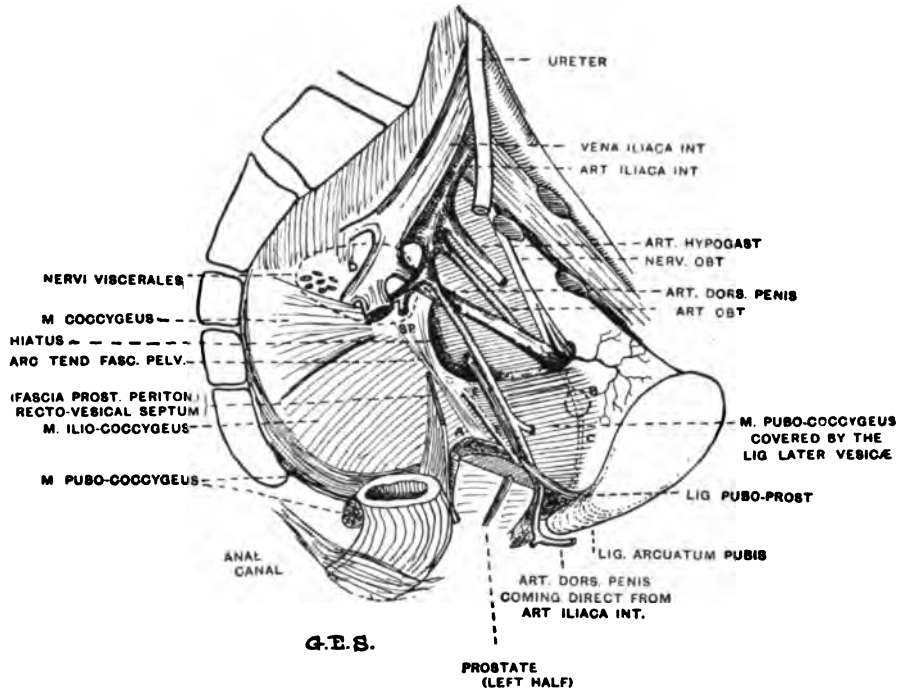


FIG. 15.

FIGS. 14 and 15 represent two parts of the left half of a pelvis from which the peritoneum has been removed Fig. 14 represents a mass consisting of bladder, vesiculæ seminales, and a group of nerves removed from the pelvis, which was thus left in the condition represented in fig. 15.

In fig. 14 the visceral plexus of nerves (which lies in immediate contact with the peritoneum) is exposed. NERV. SP. is a nerve going to the spermatic cord. In fig. 15 the dorsal artery of the penis comes directly from the internal iliac, passes forward above (in front of) the hiatus of Schwalbe, then on the surface of the lateral ligaments of the bladder (E, E, C, B), then between the latter and the pubo-prostatic ligament. The dotted line C indicates the position occupied by the abnormal dorsal artery in three other cases, in which it sprang from the obturator and pursued the course indicated (C) between the obturator internus and pubo-coccygeus; or, in other cases, it passed forward on the surface of the latter to the round hole B and then continued its course below the muscle. E E is the cut edge of the lateral ligament of the bladder, A is the vesical venous plexus cut through, SP. is the spine of the ischium. The oval area D is the place where the sacro-vesical cord—the connective tissue ensheathing the inferior vesical vessels and visceral nerves—is fixed posteriorly. The lower part of the pubo-coccygeus is seen passing, partly on to the front of the coccyx and sacrum and partly behind the anal canal—the sphincter recti or pubo-rectalis. The ilio-coccygeus does not reach above the level of the ischial spine (SP.), and the white line (ARC. TEND. FASC. PELV.) extends forward from this point. There is also an arcus tendineus musc. lev. ani curving downward at the upper border of the pubo-coccygeus (below the obturator canal) to the anterior border of the sciatic foramen (above the spine of the ischium). In the region of the upper attachment of the ilio-coccygeus the two tendinous arches are identical, and the band forms the free edge of a large lateral pelvic hiatus (fig. 15, HIATUS) which was occupied by a large plug of fat pushed downward between the sheath of the obturator internus and the ilio-coccygeus.

nerve fibres and ganglia, the visceral plexuses (fig. 3, PLEX. NERV. VESICAL.). This ligamentous band becomes firmly attached in front to the bladder,

vesiculæ seminales, and prostate. It is somewhat loosely attached to the vascular sheath; but it is the chief factor in fixing the whole sacro-vesical cord to the anterior aspect of the sacrum. The few strands of this plexus represented in fig. 13 give only a very inadequate idea of its complexity, which is shown to somewhat better advantage (from the inner side) in fig 14 (PLX. VESIC.): but the excellent figure in Spalteholz's Atlas (9, p. 768), and especially Frohse's beautiful drawings, illustrating Fränkel's memoir (22), relieve me of the necessity of making special figures to show the plexus. A study of the amazingly complicated network of fibres, which occupies the internal between the bladder and the sacrum (fig. 14), and is partly formed by fibres emerging from the anterior sacral foramina (chiefly, as a rule, the third and fourth sacral nerves; Harman, 23), will make it abundantly clear that the fibrous sheaths enclosing this forest of nerves must form a very strong band fixing the urogenital organs to the sacrum.

Taken together, the fibrous investment of this vascular cord and nerve plexus form a strong sacro-vesical ligament, which becomes indirectly attached in front to the pubes (fig. 13) and posteriorly to the front of the sacrum (especially the margins of the third and fourth anterior sacral foramina), the lesser sciatic ligaments and the dense mass of connective tissue surrounding the internal iliac vessels and sacral plexus above the iliac spine (fig. 15).

In the preparation diagrammatically represented in fig. 13, the posterior part of the sacro-vesical cord has been dissected away so as to reveal the nerves, artery, and veins, which form the nucleus, so to speak, of the band. The cord passes backward toward the sacrum on the side of the rectum, from which it is separated by loose areolar tissue. The sheaths of the nerves, which pass out of the visceral plexus into the rectum (fig. 14, NERV. HÆMORR.), form loose bands which do not in any way fix the rectum or interfere with its expansion.

The importance of such ligamentous bands as this has long been recognised in the case of the female pelvis (see the summary of literature in Rieffel, 4, pp. 462–478; and the references to it in the note by Ovenden, 24, p. 310).

In studying fig. 5 we saw that the lateral part of the sheath of the prostate (in the region marked A in fig. 13) is formed, in part, by the inner layer of the sheath of the pubo-coccygeus muscle, which is firmly attached to the triangular ligament (or perineal body—see fig. 8). Immediately behind the base of the triangular ligament (fig. 13, F) this thickened part of the sheath of the pubo-coccygeus passes on to the wall of the rectum—the lowermost part of the rectal ampulla just above the anal canal—and is firmly fixed to its surface (fig. 13A, T). The inner sheath of the levator ani

muscle extends downward as far as the anus—it is, in fact, the "rectal layer" of the visceral pelvic fascia of the text-books; but at the lower margin of the rectal ampulla (between the points A and B in fig. 4) it is thickened and attached to the rectal wall. Further back (fig. 3, FASCIA PUBO-SACRALIS) it is placed alongside the slip of pubo-coccygeus, which is passing backward to the sacrum and coccyx (compare fig. 15). The latter is usually united to its fellow of the opposite side in a mesial raphé behind the rectum. This acts as a ligament fixing the rectum to the coccyx and sacrum (see Spalteholz, 9, p. 606). But there are usually other mechanical supports for the rectum. The rectal ampulla is always firmly united by ligamentous bands to the coccyx and sacrum, but their nature and arrangement are subject to a considerable amount of variation. Often an unstriped muscle is found uniting the rectum directly to the coccyx or to the aponeurotic arch over the middle sacral artery—this is the recto-coccygeal muscle of Treitz (fig. 13A). Its morphology is discussed at some length by Holl (7, p. 267) and Rieffel (4, p. 672), so that I need not consider it further, except to state that frequently it becomes converted into a ligament, pure and simple.

In some cases we find alongside it a representative of the flexor of the tail of other mammals—the anterior sacro-coccygeal muscle (fig. 13A), which may also be converted, partially or wholly, into fibrous tissue; its sheath or the fibrous representative of the muscle itself, is often prolonged on to the rectum as well as into the aponeurosis on the upper (anterior) surface of the gluteus maximus.

In fig. 13A, T refers to the fibrous tissue passing from the surface of the levator ani into the rectum.

Thus we find stretching from the back of the pubes to the front of the coccyx and sacrum a strong hammock-like band of fibrous tissue (on each side of the middle line), which forms the chief support of the rectum and prostate. In their main features these bands resemble the pubo-sacro-genital aponeurosis of Hogge and Delbet (2, p. 238) although in some of its details it hardly agrees with the account given by the latter.

Above the recto-coccygeal ligament there are additional ligamentous bands formed by the sheaths of the nerves (fig. 13, C) and the branches of the middle hæmorrhoidal arteries passing to the rectum, but these are so loose that they permit the movement of the rectal walls that takes place during its physiological expansion.

Before leaving the discussion of these ligamentous bands I must refer to the so-called "suspensory ligament"[1] which is the subject of Melville

[1] Paterson seems to have overlooked the fact that this term has already been applied in an entirely different sense—to the superior false ligament of the bladder (Symington, 26, p. 211).

Paterson's memoir (25). This consists of the recto-vesical septum (Denonvilliers' aponeurosis) together with the lateral true ligament of the bladder (fig. 15, E E) and a (supposed) backward prolongation of these structures to "the neighbourhood of the ischial spine." The relation to it of the vessels and nerves in the sacro-vesical cord is described in these terms: "The posterior edge of the fold (suspensory ligament) is concave, and is pierced by vessels and nerves, and nearer the middle line by the vas deferens" (p. 100). There can, however, be no question of "piercing," because the two walls of Paterson's "suspensory" ligament—the recto-vesical septum and the lateral ligament of the bladder (fig. 15, E E)—never meet: the blood vessels and nerves (fig. 15, A) are placed underneath the latter and in front of the former, *i.e.* between the two walls; and as they pass backward toward the ischial spine (to D, fig. 15), they pass by the lateral edge of the recto-vesical septum (fig. 13, F D).

The only prolongations "to the neighbourhood of the ischial spine" of any of these structures consist of (*a*) an occasional extension of fibres of the lateral true ligament to strengthen the "white line," and (*b*) the sacro-vesical cord. The latter also may occasionally adhere to the "white line," but the attachment is so slight and so purely fortuitous as to be negligible.

There is nothing in these statements to shake one's belief in the correctness of the view, already enunciated by Drappier (2, p. 238) and Derry (1), that the "white line" is essentially a tendon of the ilio-coccygeus muscle.

Atkinson Stoney (27) has described, under the name "visceral pelvic fascia," the capsules of the various pelvic viscera which are left when the organs themselves are removed from subjects fixed by formalin; but he has not analysed the constitution of these capsules. He has merely indicated what parts of the capsules correspond to the various segments of the conventional pelvic fascia.

Summary.

I shall now attempt to summarise, as concisely as possible, the main facts brought to light in this examination of the pelvis.

For the sake of lucidity, and to avoid confusion, I shall deliberately avoid the use of the terms "parietal" and "visceral pelvic fasciæ," "obturator fascia," "deep layer of the triangular ligament," and "deep perineal pouch." [1]

[1] Seeing that the levator ani normally passes up almost as high as the pelvic brim, as was long ago pointed out by Luschka (28) and amply confirmed by Kollmann (11), Holl (7), Peter Thompson (12), Derry (1), and my own dissections (fig. 3), it is quite erroneous to describe the muscle as arising from the "parietal pelvic fascia," because the upper part of this fascia (the pars supradiaphragmatica of His) is merely the continuation of the muscle itself. Any subdivision of the superior aponeurosis of the levator ani into "parietal" and "visceral" parts is also quite artificial and misleading.

The objection to the use of the term "obturator fascia" is that the aponeurosis of the

The Lining of the Pelvis (fig. 15).

The pelvis is lined in the greater part of its extent by the superior aponeurosis of the levator ani muscle (the upper line of whose attachment is graphically shown in fig. 1); this is attached inferiorly to the triangular ligament and perineal body (fig. 5), to the rectum, and to a fibrous mesial raphé passing back from the rectum to the sacrum and coccyx. The rest of the pelvis is lined by the aponeurosis of the coccygeus: the mass of fibrous tissue which covers the structures (*both arteries*[1] and nerves) in the great sciatic foramen: and the periosteum on the otherwise uncovered parts of the pubes and sacrum (compare Savage's drawing of the pelvic lining in Rieffel, 4, p. 685).

The Fixation of the Prostate.

The prostate is held in position (1) by the continuity of the prostatic urethra with the other parts of the urethra, which are fixed by means of the attachment of the erectile bodies to the triangular ligament (*i.e.* to the pubic and ischial rami); (2) by the direct continuity of the anterior part of the capsule and the transverse ligament of the pelvis; (3) by the intimate connection of the lateral and posterior parts of the capsule with the triangular ligament (fig. 5) and perineal body (figs. 9, 10, and 12); (4) by its attachment to the bladder and rectum, which have other means of support.

obturator muscle takes no important share in the constitution of the pelvic fascia; and the structures which pass under this name—the fascia lunata and the upper part of the levator ani muscle (or its aponeurosis), (see fig. 3)—have nothing whatever to do with the sheath of the obturator muscle Moreover, the term "obturator fascia" is used in different senses by various writers; and it might with great advantage be discarded.

The "deep perineal pouch" has no existence in fact; and in the course of dissection it can be made only by deliberately scraping away the deep transverse muscle and the sphincter urogenitalis, with Cowper's glands. Even then it does not correspond to the descriptions found in most treatises; for it does not contain the internal pudic artery and dorsal nerve of the penis. To bring them into the artificial cavity it would be necessary to dissect away the fibrous tissue of the fascia lunata which ensheaths them. Then we should have the deep perineal pouch exposed *secundum artem*.

[1] Most writers describe the parietal pelvic fascia as placed in front of the nerves and *behind the arteries*; moreover, this part of the fascia is often considered to be identical with the aponeurosis of the pyriformis. I quite agree with all that Holl (7) says, when he vigorously protests against these views (p. 194): "Die Fascie des M. piriformis hat mit den Sog. Beckenfascien der Autoren gar nichts zu schaffen," and "Weiter sei aufmerksam gemacht, dass die grossen Stämme der Vasa hypogastrica nicht frei daliegen, sondern in einer Art Fascienschiede stecken, welche sich auf die Aeste die von den hypogastrischen Stämmen abgegeben werden, fortsetzt." If, in the dissection of the pelvis (after reaching the stage shown in fig. 14), the fat be removed from the neighbourhood of the visceral nerves (RAM. VISC PL. PUDEN.)—compare fig. 15, NERVI VISCERALES—a very dense layer of fibrous tissue will be found occupying the sciatic foramen and closely investing the internal iliac artery and vein and all their branches, as well as all the nerves. It is this dense fascia which ought to be considered as the posterior part of the pelvic fascia: it also affords attachment to the sacro-vesical cord.

The pubo-coccygeus muscle, placed on each side of the prostate, helps to support it; and the lateral ligaments of the bladder fix the bladder and prostate to its (pubo-coccygeus) aponeurosis (fig. 5).

The Mechanical Supports of the Bladder.

The bladder is held in position by (1) the urachus; (2) to a very slight extent by the ureter, superior vesical artery, vasa deferentia, and the mesodermal sheaths of these structures; (3) mainly by its continuity with the prostrate, and (4) by the lateral and anterior true ligaments.

The lateral true ligament of the bladder is a strong band, formed by a fibrous transformation of the mesodermal matrix of the small vessels on the surface of the bladder (fig. 5) and of the large vesical veins coming from the pudendal plexus and a thickening of the aponeurosis of the pubo-coccygeus muscle in continuity with it (fig. 15, E, E, B, C), so that the ligament in many cases virtually gains an attachment to the pubes (fig. 15, B, C).

The anterior true ligament is a rounded cord of smooth muscle (pubo-vesical muscle) and fibrous tissue (pubo-prostatic ligament), which fixes the bladder to the back of the pubes.

In addition to these there is the sacro-vesical cord, which acts as a supplementary support to the base of the bladder and fixes it to the sacrum and the mass of fibrous tissue in the great sciatic foramen. The vesiculæ seminales, held in position by their attachment to the prostate and vasa deferentia and to some extent by the recto-vesical septum (which is firmly fixed to the peritoneum above), are bound to the base of the bladder by the continuity of their mesodermal sheaths, and together form a rigid mass each of the constituents of which lends its support to the other.

The Rectum.

The anal canal is fixed by (1) its continuity with the skin; (2) its attachment to the perineal body; (3) the insertions of the external sphincter to the perineal body and coccyx, and (4) by the various parts of the levator ani, which support, surround, or are attached to it, either directly or by the fusion of their aponeuroses with the walls of the canal (see Holl, 7, fig. 8, p. 193), and thus, in virtue of their fixation to the triangular ligament, coccyx, and sacrum, attach the anal canal to these structures.

The rectum, apart from the anal canal, is somewhat loosely attached to the front of the sacrum by moderately strong connective tissue bands, which become definite ligaments near the fourth sacral foramina, where

they consist of the sheaths of nerves (fig. 13, C) passing directly from the spinal nerves to the rectum. On its lateral aspect, also, a loose but strong band passes from near the ischial spine to the rectal wall: it contains the middle hæmorrhoidal vessels (fig. 1, *g*) and nerves (fig. 14, NERV. HÆMORR.; and fig. 15, G).

But these are all quite loose attachments, which do not interfere with the expansion of the rectum. The only part of the rectum proper that is fixed is the lowermost part of the rectal ampulla. This is firmly fixed (1) by its attachment to the perineal body, thus uniting it with the triangular ligament and the capsule of the prostate, the former passing to the pubic and ischial rami and the latter to the body of the pubes (see figs. 8, 9, 10, 12, 13); (2) by its lateral attachment to the pubo-sacral ligament (fig. 13, B; fig. 13A, T), the thickened band of aponeurosis of the levator ani, which forms a pubo-sacral hammock supporting the prostate and the rectal ampulla; (3) by the recto-coccygeal ligaments (fig. 13A) which fix it to the coccyx and sacrum; and (4) by its continuity with the anal canal.

The Perineal Fasciæ.

These have been so concisely described in the body of this memoir that it is unnecessary to attempt to summarise the statements again.

ADDENDA ET CORRIGENDA.

As the result of a delay in the post, the proofs of the first part of this memoir (January 1908) were not read by me before publication, and certain mistakes have remained uncorrected.

On page 204, the last words of the third paragraph,—"and the sphincter of the membranous urethra (figs. 6 and 7, M. SPHINCTER UROGENITALIS)"—should form the continuation of the preceding sentence. In the first line of the footnote on page 215 the word "or" is a misprint for "os."

When writing the first part I quite overlooked Wood Jones's important memoir on the urethral and vesical musculature (*Proceedings of the Anatomical Society of Great Britain and Ireland*, May 1902), a reference to which should have been put in the legend to fig. 12. Since this work was sent to the Editors, a memoir by Dr John Cameron on "The Fascia of the Pelvis" has been published in this Journal (vol. xlii. pp. 112–125), in which the importance of the perivascular sheaths is emphasised. His account of the parietal pelvic fascia ill accords with my own observations, and the rôle of the levator ani muscle and its aponeurosis does not seem to have been fully realised. A comparison of his first figure (p. 113) and the drawings published by Wood Jones (*op. cit.*, fig. 3) and by me (fig. 12) further accentuates the discrepancy between our observations.

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THE BRAINS OF ABORIGINAL NATIVES OF AUSTRALIA IN THE ANATOMY SCHOOL, CAMBRIDGE UNIVERSITY. By W. L. H. DUCKWORTH, M.D., Sc.D., M.A.

PART III.

SECTION 3.—TABLE I., PART I.

CENTRAL HEMISPHERES OF ABORIGINES OF AUSTRALIA.

CHARACTER OR MEASUREMENT.	HEMISPHERE.								Page of Reference in Cunningham Memoir VII. (*q.v.*).
	No. 1. R.	No. 1. L.	No. 2. R.	No. 2. L.	No. 3. R.	No. 3. L.	No. 4. R.	No. 4. L.	
No.									
1. Length measured round mesial border.	172	169	211	218	201	203	204	205	p. xii[1]
2. Length measured round lateral border.	148	149	190	203	180	191	177	186	,,
3. Length of posterior limb of Sylvian fissure[2]	45	48	62	48	52	70	45	54	125
4. Sylvian angle	68° 30′	68°	73°	68°	64°	70° 30′	67°	68° 30′	131
5. Height of hemisphere above Sylvian fissure	63	64	77	75	74	76	64	65	144
6. Height of hemisphere below Sylvian fissure	32	31	35	35	26	26	28	31	144
7. Length mesially to upper end of sulcus centralis	100	108	135	126	120	129	115	116	175
8. Length laterally to lower end of sulcus centralis	67	69	92	82	87	89	80	82	175
9. Rolandic angle[3]	43°	40°	50°	45°	57°	50°	45°	56°	186
10. The size of the arcus parieto-occipitalis	18	19	22	13	16	13	14	10	237, 238
11. Length of sagittal component of sulcus intraparietalis	33	38	32	52	34	62	40	32	241
12. Length from frontal pole to mid-point of the sulcus precentralis inferior	95	89	95	80	74	86	75	70	300
13. Sagittal diameter of hemisphere	125	124·5	154	158	144	147	152	158	...
14. Pre-callosal length	17	(13·6)[4]	30	(19·4)	28	(19·4)	28	(18·4)	329[5]
15. Callosal length	66	(52·8)	75	(48·4)	75	(52·1)	73	(48)	,,
16. Post-callosal length	42	(33·6)	50	(32·2)	41	(28·5)	51	(33·6)	,,
17. Transverse diameter of cerebrum	87		107		111		91		...

[1] The measurement differs slightly from that prescribed by Cunningham, inasmuch as the arc thus measured is here limited by the longest sagittal diameter of the hemisphere.
[2] Karplus' specimen provides the following measurements:—Right hemisphere, 47 mm.; left hemisphere, 51 mm.
[3] See the notes on this angle in Part I. of this memoir.
[4] The figures in brackets are the percentage proportions of these values.
[5] From Cunningham and Telford's memoir.

Table I., Part II.

Index or Other Character.	Dimensions in Preceding List compared.	Reference to Cunningham Memoir VII.	Australian Hemispheres.							
			Right.				Left.			
			1	2	3	4	1	2	3	4
18. Relative length of posterior limb of Sylvian fissure	Nos. 2, 3	pp. 127, 129	30·4	32·6	28·9	25·4	32·2	21·1	36·6	29
19. Relative position of posterior limb of Sylvian fissure—										
(*a*) Percentage of hemisphere above fissure .	,, 5, 6	,, 144, 149	66	68·7	74	69·5	67·3	68·1	74·5	67·6
(*b*) Percentage of hemisphere below fissure .	...	...	34	31·3	26	30·5	32·7	31·9	25·5	32·4
20. Mesial fronto-Rolandic index . . .	,, 1, 7	,, 175, 183	58·7	64·4	59·7	56·3	63·3	57·8	63·5	56·5
21. Lateral fronto-Rolandic index . . .	,, 2, 8	,,	45·3	48·4	48·3	45·2	46·3	40·4	46·5	44
22. Relative size of the arcus parieto-occipitalis .	,, 1, 10	p. 238	10·4	10·4	7·96	6·86	11·2	6	6·89	4·87
23. Relative length of the sagittal component of the sulcus intraparietalis	,, 1, 11	,, 241	19·1	15·1	16·9	19·6	22·5	23·8	30·5	15·5
24. Fronto-precentral index	,, 2, 12	,, 300	40·5	50	41·2	42·3	44·9	34·4	45	37·6
25. Depth of central sulcus (mean value)[1] . .	...	...	...	...	12·7	...	...	...	12·7	...
26. Depth of intraparietal sulcus (mean value)[1] .	...	...	...	...	13·7	...	...	...	12·7	...

[1] Rolleston, *Journ. Anthr. Institute*, vol. xvii.

Table I., Part III.

Index or Character.	Right Hemisphere.							Left Hemisphere.							Both Hemispheres.							
	Mean Value in Australian Brains.	Mean Value in European Adult Brains.	Mean Value in European Fœtus, 9th month.	Chimpanzee.	Orang-utan.	Cercopithecidæ.	Cebidæ.	Mean Value in Australian Brains.	Mean Value in European Adult Brains.	Mean Value in European Fœtus, 9th month.	Chimpanzee.	Orang-utan.	Cercopithecidæ.	Cebidæ.	Mean Value in Australian Brains.	Mean Value in European Adult Brains.	Mean Value in European Fœtus, 9th month.	Mean Value in European Fœtus, 5th-6th month.	Chimpanzee.	Orang-utan.	Cercopithecidæ.	Cebidæ.
18. Relative length of posterior limb of Sylvian fissure	29·3	24·4	27·8	28·8	35·7	36·7	38·7	29·7	28	29·2	31·6	34·4	38·1	36·8	29·4	26·1	28·4	..	30·2	35	37·6	37·7
19. Relative position of posterior limb of Sylvian fissure—																						
(*a*) Percentage of hemisphere above fissure . . .	69·5	69·7	61	..	..	..	..	69·4	68·5	61·4	..	..	..	..	69·4	..	..	..	71·2	71	65·9	66·9
(*b*) Percentage of hemisphere below fissure . . .	30·5	30·3	39	..	..	..	..	30·6	31·5	38·6	..	..	..	..	30·6	..	..	..	28·8	29	34·1	33·1
20. Mesial fronto-Rolandic index .	59·8	..	..	..	..	..	..	60	..	..	..	..	..	..	60	53·3	53·5	52·7	55·9	55·5	47·7	46·3
21. Lateral fronto-Rolandic index .	46·8	..	..	..	..	..	..	44·3	..	..	..	..	..	..	45·5	43·3	42·6	41·8	39·2	39·2	40·2	43·8
22. Relative size of the arcus parieto-occipitalis	8·9	..	..	..	..	..	..	7·24	..	..	..	..	..	..	8·1	11·1	9·9	..	16·2	16·9	..	..
23. Relative length of the sagittal component of the intraparietal sulcus	17·7	..	..	..	..	..	..	23·1	..	..	..	..	..	..	20·2	22·5	24·4	..	20·4	25·7	..	..
24. Fronto-precentral index . . .	43·5	..	..	..	..	..	..	40·5	..	..	..	..	..	..	42	37·8	38	39·7	31·6	33·6	29·4	27·4

Table I.—Analysis.

I. The Sylvian angle.—The values are all so distinctively human, that the comparison with the data from the Simiidæ does not provide any more instructive results than those obtained from the study of European brains.

No. 1 R.[1]	resembles the European adult hemisphere.		
No. 1 L.	,,	,,	,,
No. 2 R.	,,	,,	,,
No. 2 L.	,,	,,	,,
No. 3 R.	,,	,,	infant and fœtus.
No. 3 L.	,,	,,	adult.
No. 4 R.	,,	,,	,,
No. 4 L.	,,	,,	,,
Mean of R.	,,	,,	,,
Mean of L.	,,	,,	,,
Mean of all	,,	,,	,,

II. Proportionate Length of the Posterior Limb of the Sylvian Fissure.

No. 1 R.	resembles in order,	(*a*) Simiidæ,	(*b*) European fœtus,	(*c*) European adult.	
No. 1 L.	,, ,,	(*a*) ,,	(*b*) ,,	adult, (*c*) ,,	fœtus.
No. 2 R.	,, ,,	(*a*) ,,	(*b*) ,,	fœtus, (*c*) ,,	adult.
No. 2 L.	,, ,,	(*a*) European fœtus,	(*b*) ,,	adult, (*c*) Simiidæ.	
No. 3 R.	,, ,,	(*a*) Simiidæ,	(*b*) ,,	,, (*c*) European fœtus.	
No. 3 L.	,, ,,	(*a*) Simiidæ (with Cercopithecidæ)	(*b*) ,,	,, (*c*) ,,	,,
No. 4 R.	,, ,,	(*a*) European adult,	(*b*) ,,	fœtus, (*c*) Simiidæ.	
No. 4 L.	,, ,,	(*a*) ,, ,,	(*b*) Simiidæ,	(*c*) European fœtus.	
Mean of R.	,, ,,	(*a*) Simiidæ,	(*b*) European fœtus,	(*c*) ,,	adult.
Mean of L.	,, ,,	(*a*) ,,	(*b*) ,,	adult, (*c*) ,,	fœtus.
Mean of all	,, ,,	(*a*) ,,	(*b*) ,,	fœtus, (*c*) ,,	adult.

III. Position of Posterior Limb of Sylvian Fissure on side of Hemisphere.

No. 1 R.	resembles in order,	(*a*) Cercopithecidæ,[2]	(*b*) European adult,	(*c*) European fœtus, Simiidæ.	
No. 1 L.	,, ,,	(*a*) European adult,	(*b*) Cercopithecidæ,	(*c*) Simiidæ.	
No. 2 R.	,, ,,	(*a*) ,,	(*b*) Simiidæ,	(*c*) Cercopithecidæ.	
No. 2 L.	,, ,,	(*a*) ,,	(*b*) ,,	(*c*) ,,	
No. 3 R.	,, ,,	(*a*) Simiidæ,	(*b*) European adult,	(*c*) ,,	
No. 3 L.	,, ,,	(*a*) ,,	(*b*) ,,	(*c*) ,,	
No. 4 R.	,, ,,	(*a*) European adult,	(*b*) Simiidæ,	(*c*) ,,	
No. 4 L.	,, ,,	(*a*) ,,	(*b*) Cercopithecidæ,	(*c*) Simiidæ.	
Mean of R.	,, ,,	(*a*) ,,	(*b*) Simiidæ,	(*c*) Cercopithecidæ.	
Mean of L.	,, ,,	(*a*) ,,	(*b*) ,,	(*c*) ,,	
Mean of all	,, ,,	(*a*) ,,	(*b*) ,,	(*c*) ,,	

IV. Rolandic Angle.

Owing to the divergence of results from those recorded in the literature, no discussion of the values of the Rolandic angle is possible. The range of variation in the Australian hemispheres at Cambridge is exceeded by that of simian hemispheres measured in the same way.

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[1] In this analysis, No 1 R., etc., are used to signify Australian brain No. 1, right hemisphere.

[2] When the European fœtal brain is not brought into comparison, it would appear in a fourth class (*d*).

V. Fronto-Rolandic Index (Mesial).

No. 1 R.	resembles in order,		(*a*)	Simiidæ,	European fœtus,	(*b*)	European adult,	(*c*)	Cercopithecidæ.	
No. 1 L.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*c*)	,,	
No. 2 R.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*c*)	,,	
No. 2 L.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*c*)	,,	
No. 3 R.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*c*)	,,	
No. 3 L.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*c*)	,,	
No. 4 R.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*c*)	,,	
No. 4 L.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*c*)	,,	
Mean of R.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*c*)	,,	
Mean of L.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*c*)	,,	
Mean of all	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*c*)	,,	

VI. Fronto-Rolandic Index (Lateral).

No. 1 R.	resembles in order,		(*a*)	European adults,	Cebidæ,	(*c*)	European fœtus,	(*d*)	Simiidæ.	
No. 1 L.	,,	,,	(*a*)	,,	,,	(*c*)	,,	(*d*)	,,	
No. 2 R.	,,	,,	(*a*)	,,	,,	(*c*)	,,	(*d*)	,,	
No. 2 L.	,,	,,	(*a*)	Simiidæ,	European fœtus,	(*c*)	Cercopithecidæ,	(*d*)	Cebidæ, adult Europeans.	
No. 3 R.	,,	,,	(*a*)	European adults,	Cebidæ,	(*c*)	European fœtus,	(*d*)	Simiidæ.	
No. 3 L.	,,	,,	(*a*)	,,	,,	(*c*)	,,	(*d*)	,,	
No. 4 R.	,,	,,	(*a*)	,,	,,	(*c*)	,,	(*d*)	,,	
No. 4 L.	,,	,,	(*a*)	,,	,,	(*c*)	,,	(*d*)	,,	
Mean of R.	,,	,,	(*a*)	,,	,,	(*c*)	,,	(*d*)	,,	
Mean of L.	,,	,,	(*a*)	,,	,,	(*c*)	,,	(*d*)	,,	
Mean of all	,,	,,	(*a*)	,,	,,	(*c*)	,,	(*d*)	,,	

VII. Relative Size of the Arcus Parieto-occipitalis.

No. 1 R.	resembles in order,		(*a*)	European fœtus,	(*b*)	European adult,	(*c*)	Simiidæ.	
No. 1 L.	,,	,,	(*a*)	,, adult,	(*b*)	,, fœtus,	(*c*)	,,	
No. 2 R.	,,	,,	(*a*)	European fœtus,	(*b*)	European adult,	(*c*)	,,	
No. 2 L.	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	
No. 3 R.	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	
No. 3 L.	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	
No. 4 R.	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	
No. 4 L.	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	
Mean of R.	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	
Mean of L.	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	
Mean of all	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	

VIII. Relative Length of Sagittal Part of S. Intraparietalis.

No. 1 R.	resembles in order,		(*a*)	European adult,	(*b*)	Simiidæ,	(*c*)	European fœtus.	
No. 1 L.	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	
No. 2 R.	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	
No. 2 L.	,,	,,	(*a*)	European fœtus,	(*b*)	,,	(*c*)	European adult.	
No. 3 R.	,,	,,	(*a*)	,, adult,	(*b*)	,,	(*c*)	,, fœtus.	
No. 3 L.	,,	,,	(*a*)	,, fœtus,	(*b*)	,,	(*c*)	,, adult.	
No. 4 R.	,,	,,	(*a*)	European adult,	(*b*)	,,	(*c*)	European fœtus.	
No. 4 L.	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	
Mean of R.	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,	
Mean of L.	,,	,,	(*a*)	European adult and fœtus equally,	(*b*)	European adult and fœtus equally,	(*c*)	Simiidæ.	
Mean of all	,,	,,	(*a*)	European adult,	(*b*)	Simiidæ,	(*c*)	European fœtus.	

IX. Fronto-precentral Index.

No. 1 R.	resembles in order,	(*a*) European fœtus (5th mo.),	(*b*)	European adult, European fœtus at term,	(*d*) Simiidæ.					
No. 1 L.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*d*)	,,	
No. 2 R.	,,	,,	(*a*	,,	,,	(*b*)	,,	(*d*)	,,	
No. 2 L.	,,	,,	(*a*) Simiidæ,			(*b*)	,,	(*d*)	European fœtus (5th month).	
No. 3 R.	,,	,,	(*a*) European fœtus (5th mo.),			(*b*)	,,	(*d*) Simiidæ.		
No. 3 L.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*d*)	,,	
No. 4 R.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*d*)	,,	
No. 4 L.	,,	,,	(*a*)	European adult, European fœtus at term,		(*b*)	European fœtus (5th month),	(*d*)	,,	
Mean of R.	,,	,,	(*a*) European fœtus (5th mo.),			(*b*)	European adult, European fœtus at term,	(*d*)	,,	
Mean of L.	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*d*)	,,	
Mean of all	,,	,,	(*a*)	,,	,,	(*b*)	,,	(*d*)	,,	

X. Proportions of Hemisphere with regard to Corpus Callosum.

(*a*) Frontal Component—

No. 1 resembles in order,	(*a*) Microcephalus,	(*b*) adult European,	(*c*)	Newly-born European. Chimpanzee.				
No. 2	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,
No. 3	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,
No. 4	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,
Mean	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,

(*b*) Corpus Callosum—

No. 1 resembles in order,	(*a*) Microcephalus,	(*b*) adult European,	(*c*)	Newly-born European. Chimpanzee.				
No. 2	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,
No. 3	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,
No. 4	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,
Mean	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,

(*c*) Occipital Component—

No. 1 resembles in order,	(*a*) adult European,	(*b*) Microcephalus,	(*c*)	Newly-born European. Chimpanzee.				
No. 2	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,
No. 3	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,
No. 4	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,
Mean	,,	,,	(*a*)	,,	(*b*)	,,	(*c*)	,,

TABLE II.

CHARACTER.	Percentage in all available Australian Hemispheres.	Number of all available Australian Hemispheres.	Percentage in Australian Hemispheres at Cambridge.	Actual Number of Hemispheres at Cambridge.	Percentage in Swedish Hemispheres (Retzius).	Actual Number of Swedish Hemispheres.	Percentage in British Hemispheres (Cunningham).	Actual Number of British Hemispheres.	Percentage in European (fœtal) Hemispheres (Duckworth).	Actual Number of fœtal Hemispheres.	Percentage in Hemispheres of the Simiidæ (Duckworth).	Actual Number of Hemispheres of the Simiidæ studied.	ADDITIONAL DATA, ETC.
Sulcus precentralis inferior joins S. frontalis inferior	60	10	62·5	8	77	100	28·3	50	50	14	100	10	Eberstaller gives 76 per cent.
S. precentralis inferior joins S. transversus inferior	..	10	?	8	..	..	..	..	0	14	0	10	
S. fronto-marginalis or S. radiatus (Eberstaller), present and detached	60	10	50	8	?	..	rare	57	78·6	14	80	10	Cu. p. 263.
S. precentralis marginalis—present and detached	50	..	50	8	..	..	"very frequent"	..	35·3	17	0	10	
S. precentralis medius—present and detached	12·5	..	12·5	8	..	..	"inconstant"	..	5·9	17	80	10	
S. precentralis superior joins S. frontalis superior	87·5	..	87·5	8	..	..	"exception"	..	41·2	17	80	10	Eberstaller, 100 per cent.
S. frontalis medius—one part, with "W" detached	70	10	75	8	? 24	100	"very variable"	..	21·4	14	10	10	
two parts, with "W" detached	10	10	12·5	8			..	..	14·2	14	0	10	
continuous with "W"	10	10	12·5	8	33	100	..	..	57	14	20	10	
["W" = *Wernicke's S. fronto-marginalis.*]													
Relative length of terminal branches of sulcus "W"—									(38·4)	(13)	(20)	(10)	
Sulcus "W" is bifid in	71·4	7	71·4	7	19	..	(? 72·1)	(?100)	100	5	100	2	In European fœtuses and Simiidæ the percentage is based upon the number of hemispheres in which the condition occurred (viz. 5 and 2 respectively), not on the total number observed.
Lateral branch is longest in	28·3	7	28·3	7	.	..	..	..	(0)	(13)	(10)	(10)	
									0	5	50	2	
Mesial branch is longest in	14·2	7	14·2	7	..	..	..	..	(30·7)	(13)	(10)	(10)	
									80	5	50	2	
Both branches of equal length in	28·3	7	28·3	7	..	..	..	..	(7·7)	(13)	(0)	(10)	
									20	5	0	2	
S. frontalis mesialis—present and detached	87·5	8	87·5	8	..	..	100	?	11·8	17	0	10	Often absent from negro brains (Cunningham).
joins other sulci	12·5	8	12·5	8	..	..			5·9	17	0	10	
Orbital sulci—simple	60	10	75	8	66·6	..	..	..	82·2	17	100	10	
complex	20	10	12·5	8					17·7	17	0	10	
radiate	10	10	12·5	8	33·4	..	..	..	5·9	17	10	10	

TABLE II.—*continued.*

CHARACTER.	Number of all available Australian Hemispheres.	Percentage in all available Australian Hemispheres.	Percentage in Australian Hemispheres at Cambridge.	Actual Number of Hemispheres at Cambridge.	Percentage in Swedish Hemispheres (Retzius).	Actual Number of Swedish Hemispheres.	Percentage in British Hemispheres (Cunningham).	Actual Number of British Hemispheres.	Percentage in European (fœtal) Hemispheres (Duckworth).	Actual Number of Fœtal Hemispheres.	Percentage in Hemispheres of the Simiidæ (Duckworth).	Actual Number of Hemispheres of the Simiidæ studied.	ADDITIONAL DATA, ETC.
Sulcus intraparietalis—four parts independent (I)	: :	: :	[12·5] *	8	9	: :	[6·3] *	63	5·9	17	0	10	* Data not precisely corresponding to those for European fœtus or Simiidæ.
four parts confluent (IV)	: :	: :	[12·5] *	8	55	: :	[60·3] *	63	5·9	17	40	10	
ramus postcentralis superior free, remainder confluent (II)	10	[30]	[25] *	8	11	: :	[19·1] *	63	35·4	17	60	10	† Cunningham's data give 55 per cent.
ramus occipitalis free	: :	: :	0	8	: :	: :	[36·8] *	63	47·2 †	17	0	10	The brain of the "Hottentot Venus" was of this type (vIz. III).
postcentral rami confluent, sagittal and occipital rami confluent (III)	10	50	[50]	8	17	: :	[11·1] *	63	[? 23·5]	17	0	10	
postcentral rami confluent and separate from all other combinations	10	47·2	?	: :	: :	: :	: :	: :	23·5	17	: :	10	
[*Roman numerals refer to Cunningham's types.*]													
S. postcentralis medius present	10	0	0	8	4	: :	: :	: :	5·54	18	0	10	
S. calcarinus (and retrocalcarinus)—													
continued to lateral aspect	8	37·5	87·5	8	: :	: :	: :	: :	16·6	18	40	10	Bolton gives for European brains 87·5 per cent.
bifid posteriorly	8	50	50	8	: :	: :	: :	: :	38·8	18	50	10	Bolton states that the upper is on the average the shorter of the two.
upper branch of bifurcation longer	8	50	50	8	: :	: :	: :	: :	16·6	18	50	10	
S. limitantes—both present	9	77·8	71·4	7	: :	: :	: :	: :	73·2	15	? 30	?	
upper only	9	: :	: :	7	: :	: :	: :	: :	20	15	10	10	
lower only	9	77·8	71·4	7	: :	: :	: :	: :	6·7	15	10	10	
S. occipitalis lunatus—present	10	60	50	8	: :	: :	: :	: :	41·2	17	100	10	
S. occipitalis superior—present	8	100	100	8	: :	: :	: :	: :	50	18	100	10	
joins S. retrocalcarinus	8	87·5	87·5	8	: :	: :	: :	: :	16·6	18	0	10	
joins S. occipitalis inferior	8	12·5	12·5	8	: :	: :	: :	: :	0	18	0	10	
joins Sulci sulcus	8	50	50	8	: :	: :	: :	: :	0	18	0	10	
joins S. occipitalis lunatus	8	0	0	8	: :	: :	: :	: :	5·5	17	?	10	
S. occipitalis inferior—present	: :	: :	100	: :	: :	: :	: :	: :	94	16	100	10	
joins S. occipitalis superior (see under S. occipitalis superior)													
S. prelunatus—present	10	40	25	8	: :	: :	: :	: :	17·6	17	70	10	
joins S. occipitalis lunatus	10	10	25	8	: :	: :	: :	: :	17·6	17	70	10	
S. paramesialis—present	10	20	25	8	: :	: :	: :	: :	29·4	17	30	10	
joins S. occipitalis lunatus	10	20	25	8	: :	: :	: :	: :	29·4	17	80	10	

Sulcus occipitalis transversus (ramus occipitalis of the S. intraparietalis) reaches S. occipitalis lunatus	60	10	50	8	..	..	..	..	5·8	17	100	10	*i.e.* in all cases in which the S. lunatus is present in Australian brains, but only 14·3 per cent. of such cases in the fœtus.
S. paracalcarinus—present	100	8	100	8	..	..	..	..	73·2	15	80	10	
S. limitans precunei—present	100	9	100	7	..	..	..	..	93·2	15	100	10	
Incisura parieto-occipitalis—present	100	9	100	7	..	..	..	..	73·2	15	80	10	
Gyrus cunei—present but submerged	?	9	100	7	..	..	..	..	66·6	12	80	10	
—exposed	0	9	0	7	..	..	3·9	127	20	15	70	10	
Annectant gyri in S. retrocalcarinus—anterior present	66·6	6	66·6	6	..	..	..	..	89	9	20	8	
posterior present	100	6	100	6	..	..	..	..	100	9	80	8	
Arcus intercuneatus—present	100	8	100	8	..	..	..	..	72·8	11	100	9	
fully exposed	42·8	7	42·8	7	..	..	..	..	18·2	11	33·3	9	
S. temporalis primus—upturned	80	10	75	8	..	..	..	..	86·6	15	100	10	
joins S. intraparietalis	12·5	8	12·5	8	..	..	..	..	11·8	17	10	10	
joins S. prelunatus	12·5	8	12·5	8	..	..	..	..	0	17	20	10	
single sulcus	70	10	75	8	..	..	..	..	46·5	15	90	10	
two sulci	10	10	25	8	29	100	..	..	31·3	16	10	10	
S. temporalis secundus—one sulcus	37·5	8	37·5	8	..	..	..	..	6·2	16	40	10	
two sulci	12·5	8	12·5	8	..	..	..	..	20	15	40	10	
three or more sulci	60	10	50	8	..	..	..	..	60	15	20	10	
S. temporalis tertius—present	100	10	100	8	..	..	..	..	94	17	100	9	In Simiidæ it is difficult to distinguish from S. occipitalis inferior.
opercular	50	8	50	8	..	..	..	..	57	14	100	10	In all Cercopithecidæ (100 per cent.).
single	50	8	50	8	..	..	..	..	37·5	16	33·4	9	
two or more sulci	50	8	50	8	..	..	..	..	43·5	16	66·6	9	
Gyrus temporalis primus—constricted	40	10	50	8	..	..	..	..	26·5	15	10	10	
S. collateralis—bifid posteriorly	90	10	87·5	8	..	..	..	..	54	13	75	8	
interrupted	10	10	12·5	8	..	..	..	..	0	11	0	8	
ends in a T-piece	12·5	8	12·5	8	..	..	..	..	23	13	0	8	
joins S. calcarinus (or retro-calcarinus)	12·5	8	12·5	8	..	..	..	..	18·2	11	25	8	
joins whole or part of fissura rhinalis	50	8	50	8	..	..	..	..	21·4	14	0	8	
Temporal pole projecting far beyond uncus	100	10	100	8	..	..	..	..	71·4	14	60	10	
S. intercalaris—one sulcus	55·6	9	42·8	7	41	100	..	..	60	15	90	10	
two sulci	22·3	9	28·5	7	44	100	..	..	26·5	15	10	10	
three sulci	11·2	9	14·3	7	14	100	..	..	13·3	15	0	10	
four sulci	11·2	9	14·3	7	1	100	..	..	0	15	0	10	
partly joined to incisura cinguli	30	10	37·5	8	..	..	..	..	31·2	16	20	10	
" " S. compensatorius	30	10	12·5	8	..	..	..	..	6·6	15	40	10	
ends close to S. centralis	60	10	50	8	..	..	..	..	78·5	14	70	10	In the Papuan brain described by Bolk (*Petrus Camper*) the ending is far removed from the sulcus centralis.
with marked branch anterior to ending of S. centralis	100	10	100	8	..	..	..	..	28·5	14	40	10	
S. compensatorius—present	100	10	100	8	..	..	..	..	94	16	100	10	
single	10	10	12·5	8	..	..	..	..	93·75	16	80	10	
two sulci	50	10	50	8	..	..	..	..	6·25	16	20	10	
three sulci	20	10	25	8	..	..	..	..	0	16	0	10	
four sulci	10	10	12·5	8	..	..	..	..	0	16	0	10	
tri-radiate	10	10	12·5	8	..	..	..	..	0	16	0	10	
Incisura cinguli—present	50	10	62·5	8	..	..	..	..	87·5	16	?	0	
Genual and rostral sulci	100	10	100	8	..	..	..	..	100	14	100	10	
Genual sulcus joins S. intercalaris	30	10	12·5	8	..	..	..	..	64	14	100	10	
Rostral sulcus joins S. intercalaris	77·8	9	85·7	7	..	..	..	..	?	0	?	0	

Section 4.—Summary and Conclusions.

Having reviewed the principal anatomical features of the aboriginal Australian cerebra, I must now make an attempt to summarise the results, so as to ascertain the position in which these brains are placed by the comparison with those of the white races.

In about eighty-five instances (*cf.* Table I., Part III., and Table II.) the comparison of these cerebra with those of European origin has been exhibited in a numerical form of expression. At first sight the determination of the percentage of features in which the two classes agree seems to provide the readiest method of drawing up this summary.

But such a determination and such a method are open to adverse criticism on the ground that one would thereby attribute the same weight to each test, *i.e.* to each character employed in the comparison. In reality, however, one is not justified in treating all these characters as of equal significance. Some are undoubtedly of much more value (from the comparative point of view) than others.

For this reason it is necessary to make a selection of the more important characters, and upon these to base the comparison. I have selected accordingly fifteen different tests or criteria, and believe that they include those of the greatest value, so far as our present knowledge allows us to judge, both for the comparison of the brains of various human races *inter se*, or for that of the brains of the Hominidæ with those of the Simiidæ.

The characters will now be enumerated as follows, and it is to be noted that they are arranged not in an order of merit as regards their diagnostic value, but in the order in which they have been considered in the description in Section 2.

1. The proportionate length of the corpus callosum.
2. The curvature of the fissura rhinalis.
3. The operculation of the central lobe or insula.
4. The conformation and position of the posterior limb of the fissura Sylvii.
5. The fronto-Rolandic indices.
6. The fronto-precentral index.
7. The sulcus frontalis mesialis and the sulcus precentralis marginalis.
8. The sulcus intraparietalis.
9. The sulcus retrocalcarinus.
10. The sulcus occipitalis lunatus.
11. The gyrus cunei and the annectant gyri in the sulcus retrocalcarinus.
12. The fossa parieto-occipitalis.

1. The proportionate length of the corpus callosum (ref. Section 2, paragraph 1, *g*).

In this respect the Australian brains are all alike. They resemble in order: first, the microcephalic European brain; secondly, the normal adult European brain; thirdly, the brains of the newly-born European infant and of the Simiidæ.

This resemblance to the microcephalic type is certainly of interest. When compared with normal adult European brains, those of aboriginal natives of Australia are, of course, microcephalic, though to a lesser degree than the congenital (European) idiots to which the term is now conventionally applied. I am inclined to think that the peculiar proportion of the corpus callosum in such brains is determined by mechanical conditions regulating the growth of the cerebrum as a whole, and that it is not due so directly to either a pathological or a racial factor in development. In this connexion it may be remarked that the gap between the aboriginal and the idiotic microcephalous individual in respect of mental attainments is enormous.

It will be also noted that in this respect (viz. the proportionate length of the corpus callosum) the Australian brains are not very closely approached by those of the Simiidæ.

2. The curvature of the fissura rhinalis (ref. Section 2, paragraph 2, *d*).

The indications are here less defined than in the preceding instance, but in one hemisphere the peculiarity of a boldly-curved fissura rhinalis associates the Australian brain with those of lowly human types, such as the negroes of the Soudan and of the West Coast of Africa. This particular feature also occurs in the Simiidæ.

The single occurrence mentioned was in a right hemisphere.

This test, like the preceding one, provides some evidence of inferiority in the aboriginal Australian brain.

3. The operculation of the insula (ref. Section 2, paragraph 3, *b*).

As regards the development of opercular folds around the insula, the Australian brain resembles those of the Simiidæ, of the (European) human fœtus, and of the microcephalic (European) idiot.

Mere exposure of the insula is not a sufficient basis for such a statement, for the insula may be considerably exposed by simply withdrawing with violence the membranes and vessels of the Sylvian fissure.

But apart from exposure of the insula, it is found that the opercula, especially on the orbital side, are less exuberant than in the cerebra of Europeans.

No marked difference is detected in the Australian brain between the right and left hemispheres. The greatest deficiency occurs in a left hemisphere (No. 3).

The conclusion is that the Australian brain presents a lowly type of conformation, not necessarily reproducing a simian phase with exactness, but rather a stage interpolated between the brains of the higher Simiidæ on the one hand, and those of the most highly-developed Hominidæ on the other. If, in the absence of direct evidence, one may hazard a guess, it would be that this stage is next in advance to that of Pithecanthropus erectus.

4. The posterior limb of the fissure of Sylvius (ref. Table I., "Analysis").

Three points are of special value in connexion with the posterior limb of the fissure of Sylvius. In none of these is there any difference between the hemispheres of the right and left sides.

(*a*) The Sylvian angle reveals no difference between the Australian and the European brain, except in the case of the well-preserved Australian brain No. 3, which in this respect resembles that of the (European) infant or fœtus, but is not distinctly simian.[1]

(*b*) In respect of the relative length of the posterior limb of the fissure of Sylvius, the Australian brain is distinctly simian, but does not so nearly resemble the brains of European adults or infants.

(*c*) As regards the position of the posterior limb of the fissure of Sylvius on the lateral convexity of the hemisphere, there is no appreciable difference between the Australian and the (adult) European brain.

5. The fronto-Rolandic indices (ref. Table I., "Analysis").

With regard to these indices, the following conclusions were drawn:—

(*a*) The upper fronto-Rolando index: the right and left hemispheres are alike, resembling in succession—

(i) Cerebra of the Simiidæ and of the European fœtus equally.
(ii) Cerebra of adult Europeans.
(iii) Cerebra of the Cercopithecidæ.

(*b*) The lower fronto-Rolandic index: the right and left hemispheres are alike, and resemble in succession—

(i) Cerebra of European adults and of the Cebidæ equally.
(ii) The cerebrum of the (European) fœtus.
(iii) Cerebra of the Simiidæ.

On the whole, therefore, the status of the Australian brain is lowly, *i.e.*

[1] *Cf.* also the operculation of the insula in this hemisphere.

infantile or simian, but to some extent the conformation may be regarded as peculiar to the aboriginal race, for there is not exact correspondence with any of the types to which reference has been made for purposes of comparison.

6. The fronto-precentral index (ref. Table I., " Analysis ").

The fronto-precentral index provides a direct means of comparison. No difference is found to obtain between the right and the left hemispheres of the Australian brain. It is further found that the Australian cerebra resemble in order—

(i) Those of the European fœtus at the fifth month.
(ii) Those of adult and of (ninth month) fœtal Europeans equally.
(iii) Those of the Simiidæ.

From these comparisons it appears that the Australian brain is of a lowly, infantile, or fœtal human type, but not distinctly simian.

7. The sulcus frontalis mesialis and the sulcus precentralis marginalis (ref. Section 2, paragraph 4, " The frontal region ").

These sulci have been regarded as distinctively human characters. The following notes provide a summary of the observations made on their occurrence in the aboriginal Australian brain.

(*a*) The sulcus frontalis mesialis is present in each hemisphere of every brain, being represented by a series of short furrows or grooves. There is no appreciable difference in this respect between these brains and those of Europeans, unless it should be in the depth of the sulci. Nor is there any difference between the right and left hemispheres.

(*b*) The frequency, and indeed the occurrence, of this sulcus is characteristic of the highest types of human cerebrum, which the Australian brain is shown herein to resemble. No difference obtains between the right and left hemispheres in respect of this character.

8. The sulcus intraparietalis (ref. Section 2, paragraph 5, " The parietal region ").

The conformation of the intraparietal sulcus is an important means of comparison. In the detachment of the sulcus postcentralis superior from the rest of the intraparietal complex, the left hemisphere of the Australian cerebrum is more simian than the right. The Australian brain stands nearer to the simian type than the European, and is in this respect on a par with the brains of African negroes. At the same time, the Australian brains are less simian than those of many fœtal Europeans.

The striking characteristic is thus seen to be the similarity between the Australian and the African negro brains, while both alike approach the simian type of conformation.

9. The sulcus retrocalcarinus (ref. Section 2, paragraph 6, "The occipital region").

In the Australian brain this sulcus resembles its homologue in the brains of the Simiidæ and of the (European) fœtus. The left hemisphere is of a distinctly lowlier type than the right. An important point, whereby this difference between the hemispheres is constituted, affects the relative development of the cortical visual and the great "posterior association" centres. In the brains of lowlier type (such as those of the aboriginal Australian, of the European fœtus, or of the anthropoid ape) as compared with those of higher type, as well as in the left hemisphere as compared with the right, the latter, *i.e.* the posterior association centre, has not fully developed, and more of the cortex of the lateral aspect of the hemisphere is therefore concerned with visual impressions. In the higher types the whole extent of the cortex has increased, and one consequence of this increase (which affects the posterior association centre especially) is that the visual area on the lateral aspect becomes relatively smaller in extent.

From these considerations it is clear that the sulcus retrocalcarinus is a most valuable criterion of cerebral development; and, in fact, this and the following sulcus (the sulcus occipitalis lunatus) provide what are perhaps the most valuable tests at present available.

10. The sulcus occipitalis lunatus (ref. Section 2, paragraph 6, "The occipital region").

This sulcus (representing in the human brain the sulcus called affenspalte in those of the lower Primates) is more frequent in the left than in the right hemispheres of the Australian brains. It is quite distinct in two hemispheres, and this frequency constitutes a very distinctly simian trait in the Australian cerebra. Not only is morphological inferiority denoted hereby, but there is a further indication that the visual cortical area is relatively extensive on the lateral surface of the hemisphere, while the posterior association centre is correspondingly undeveloped (*cf.* paragraph 9).

11. The gyrus cunei and the annectant gyri of the sulcus retrocalcarinus (ref. Section 2, paragraph 6, "The occipital region").

In the conformation of these gyri the aboriginal Australian brain is not differentiated from those of adult Europeans. It is neither of fœtal nor

of infantile type, nor is there any difference between the right and the left hemispheres.

12. The fossa parieto-occipitalis (ref. Section 2, paragraph 6, "The occipital region").

The conformation of the cortex in the vicinity of this fossa provides a test of the morphological status of the brain.

The Australian brain is here shown to be of a lowly type (brain No. 4 being most distinctly so), resembling particularly the brains of Soudanese negroes, and, in a lesser degree, those of the Simiidæ. No specially fœtal or infantile characters were detected. There is no appreciable difference between the two hemispheres.

Final Summary.

A. The study of the fifteen characters thus completed leads to the following classification of results:—

In five instances the Australian brain resembles that of the adult European.

In five instances the Australian brain is distinctly simian (in two of these characters it is also similar to the brain of the European fœtus).

In three instances the Australian brain is distinctly "fœtal" (resembling in two of these features the brains of the Simiidæ).

In three instances the Australian brain is "lowly," resembling the brains of negroes, and, less definitely, those of the European fœtus and of the Simiidæ.

In one instance the Australian brain resembles that of the (European) microcephalous idiot, and is not distinctly simian or fœtal.

B. Turning to differences between the right and left hemispheres, it appears that the left hemisphere of the Australian brain is "lowlier" than the right in the three following respects:—

(*a*) In the greater tendency of the ramus postcentralis superior of the sulcus intraparietalis to remain separated from the other components of that sulcus.

(*b*) In the simplicity (straightness) of the sulcus retrocalcarinus, and its tendency to continuity with the sulcus occipitalis superior, and thus to extend apparently to the lateral convexity of the cerebral hemisphere.

(*c*) In the greater frequency of the occurrence of the sulcus occipitalis lunatus.

C. Sexual Differences.—Of the four brains, three are male and one female. The latter is the smallest, and, unfortunately, the worst preserved of the series. The latter circumstance renders it practically impossible to state clearly that any distinctive features characterise the female as contrasted with the male aboriginal brain. The following points seem, however, worthy of mention.

(*a*) In both hemispheres of the female brain the ramus postcentralis superior of the sulcus intraparietalis is separated from the other components of that sulcus. (*Cf. B* (*a*), *supra.*)

(*b*) In the female brain is found the characteristic difference between the right and left hemispheres, as regards the sulcus retrocalcarinus. (*Cf. B* (*b*), *supra.*)

(*c*) On the other hand, the sulcus occipitalis lunatus is not identifiable with certainty in the female brain.

(*d*) The right hemisphere of the female brain bears a fissura rhinalis resembling that found in many Soudanese negroes, and also in the Simiidæ.

(*e*) The inferior precentral sulcus of the right (female) hemisphere runs into the fissure of Sylvius. (This confluence is supposed to be of more frequent occurrence in female than in male brains of the European races.) On the left side of the female aboriginal Australian brain a connexion is formed (possibly through the intervention of the sulcus subcentralis anterior) between the same two fissural elements.

(*f*) The orbital, mesial frontal, and lower temporal sulci are short and straight, and thus of lowly type in the female brain.

It is particularly to be regretted that this female brain is not in a better state of preservation, for, as Elliot Smith has shown (*cf.* E.S.Gov., p. 150), in the negro races female brains may present a striking combination of lowly cerebral characters. These may be associated with the absolutely smaller size of such specimens.

D. Of the three remaining brains, No. 3, the only one previously described (*cf.* Rolleston, J.A.I., vol. xvii.) is, on the whole, distinctly the lowliest, so much so that it might seem at first sight to falsify one's idea of the "average" conformation, since it is included in such a short series. But comparison with the brain described by Karplus (*cf. Obersteiner's Arbeiten*, ix.) shows that such a combination of lowly characters is not unusual in Australian cerebra. Brain No. 2 of the Cambridge series is the most highly developed, while No. 4 occupies an intermediate position between Nos. 2 and 3.

E. While it is at present possible to detect some features of inferiority in such brains as these, it is not yet possible to define a particular racial type. Nor is it possible to differentiate between the aboriginal Australian and the Soudanese negro in respect of cerebral conformation.

For one reason or another all the four brains of the Cambridge series would have attracted attention had they been submitted for investigation along with a large collection of European brains. The net result of further examination would have been the detection of certain characters which are of lowly morphological value, and, in the present state of knowledge, it would have been justifiable to assign the brains to a lowly and probably darkly-coloured race. I think that when a greater number of examples has been examined, it will be possible to go further and to distinguish, for instance, between the negroes of Africa and of Australasia (including aboriginal natives of Australia). Beyond this it does not seem to me probable that anatomical investigation will confer any power of racial diagnosis.

The foregoing account is of a general nature only, as I desired, in the first instance, to place on record the principal anatomical characters of the specimens. Later, I hope to be able to deal with some special points, so far as the material permits.

DEVELOPMENT OF THE SPLEEN.

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I. INTRODUCTORY.

THE question of the origin and early development of the spleen has been the object of researches since the year 1867. A considerable amount of literature has accumulated since that time, in which the authors dealing with different classes of Vertebrata, and even those who have studied the question in the same animals, have arrived at widely differing conclusions.

Some have believed the spleen to be derived from the mesenchyme of the dorsal mesentery, with or without the participation of the cœlomic epithelium; some consider the cœlomic epithelium to take the most important part in its development. Some, again, state that it arises together with the pancreas, while others believe it to have its origin in the endodermal epithelium of the alimentary canal.

1. The origin from the pancreas has been supported by Götte in 1867 and Schenk in 1873, both of whom were dealing with birds. Kupffer in 1892 claimed to have found the spleen in ganoids arising as a diverticulum of the pancreas.

Woit in 1897 states that in birds and in Siredon it arises "in genetic relation with the pancreas," but does not consider this to be the case with Rana. Glas (1900) describes a "lieno-pancreas" in Tropidonotus, with a duct leading into the intestine. Orrù, Efisio (1902), also gives the pancreas a share in the formation of the spleen. I may quote in this connection from Schenk (iv. p. 627). His personal observations apply only to the chick and mammals.

"Das Mesenchym, welches die Hauptmasse der für das Pankreas bestimmten Mesodermgebilde gibt, hängt innig mit jenem Theile des Mesenchyms zusammen, welches die Anlage der Milz bildet." He considers that the spleen arises together with the pancreas, but is part of the mesoderm into which the pancreatic diverticulum grows. Kupffer, on the other hand (quoted by Laguesse), definitely gives the spleen an endodermal origin. In the Sturgeon he found four pancreatic buds, two dorsal and two ventral. The dorsal posterior diverticulum, according to him, divides into three branches: of these the right continues pancreatic in structure, the middle one forms the sub-chordal lymphoid tissue, while the left forms the spleen anlage.

2. Müller (1871), Toldt (1889), Janòsik, and Giannelli all give the cœlomic epithelium the major part in the formation of the spleen.

I quote from Müller's paper (iii. p. 260): "Bei allen Wirbelthieren geht die Milz aus einem Abschnitt des Peritonäum hervor. . . . Die erste Anlage tritt auf in Form einer gleichformigen Verdickung des Peritonäum, bedingt durch Vermehrung der dasselbe zusammensetzenden embryonalen Bildungszellen."

Toldt also (ix. pp. 989, 990) states that in the human embryo the spleen begins by a thickening of the cœlomic epithelium, which becomes cubical and splits into layers. Janòsik (xiv. pp. 71, 72) points out the distinction between the mesenchyme and the mesothelium, and states that the proliferation of the latter forms the spleen anlage. This was particularly clear in *Lacerta agilis*. He finds no genetic relation between the spleen and the dorsal pancreas, though they are in close contact in Lacerta.

3. Various writers, from Peremeschko in 1867 (I) to Pinto in 1904, have affirmed that the spleen is mesodermal in origin.

Laguesse deals very fully with the question of the formation and regeneration of blood corpuscles in the spleen in fishes, and considers its relation to the primitive sub-intestinal vein a very important one. The spleen is, he says, "une sorte de reliquat du mésenchyme embryonnaire destiné à la régéneration des globules du sang, et où les éléments conjonctifs et vasculaires restent confondus comme ils l'étaient dans le mésenchyme primitif" (x. p. 491).

And again, "Au point de vue histologique, la rate est d'abord une simple élevure du mésenchyme intestinal, et formée comme lui d'un réseau de cellules anastomosées; elle s'en distingue par la présence d'un grand nombre d'éléments ne prenant point part à la formation réticulée et restant arrondis dans les mailles: ce sont les cellules mères des futurs éléments libres de la pulpe. A aucun moment l'épithélium péritonéal ne parait prendre part à la formation du tissu splénique proprement dit . . . ." (x. p. 476).

Tonkoff, who deals in his paper entirely with the Amniota, concludes that the spleen in all these forms is entirely mesodermal in origin, but does not deny the possibility of the development being different in Fishes and Amphibia (xxiii. p. 454).

"Auf jeden Fall ist das Gewebe der jugendliche Milzanlage in histologische Beziehung identisch mit dem Mesenchym des Darmkanales—es handelt sich um die nämlichen rundlichen embryonalzellen, eingelagert in den Zwischenraümen zwischen verästelten unbeweglichen Zellelementen."

In contradistinction to Janòsik, Tonkoff does not make any essential distinction between the cœlomic epithelium and the mesenchyme (xxiii. p. 453): "Bei der Entwickelung der Milz hingegen handelt es sich um eine Zellabspaltung von dem Cœlomepithel, wobei die abgelösten Zellen sofort dem Epithel fremd werden, und von Elementen des sonstigen Mesenchyme nicht zu unterscheiden sind."

Pinto, to whose recent and detailed work I must refer more than once, believes the spleen to be of mesodermal origin, with the participation of the cœlomic epithelium. He says (xxvi. p. 391): "Mi pare adunque che si debba concludere che anche negli Anfibi la Milza è un organo di natura mesenchimale, e che è data dall' accrescimento e dalla differenziazone delle cellule del mesenterio, cellule che, qualunque sia la loro origine primitiva, vanno considerate all' epoca in cui danno origine alla milza come elementi mesenchimale."

4. Maurer, whose conclusions differ widely from other authors, states that the spleen is of endodermal origin, and that it is formed by the mitosis of certain cells in the intestinal epithelium, which divide in a plane transverse to the surface of the intestine. The new cells are extruded into the surrounding mesenchyme, where they collect round the walls of small intestinal branches of the mesenteric artery. They then, according to Maurer, travel upwards in the walls of the arterial branches, until they arrive at the main trunk, and there collect to form the anlage of the spleen. He states that he found these cells, which he considers to be the first

lymphoid elements, appearing around the small terminal branches of the arteries, before they could be traced at all on the main branches, or on the mesenteric trunk itself. He does not consider that any possible forerunners of lymphoid cells can be found in embryos of 4·6 mm. ano-buccal length (about 11 mm. total length), while in embryos of 6 mm ano-buccal length he finds such forerunners only in the mesenchyme surrounding the intestine around the walls of the smallest terminal branches of the artery. He says (xi. pp. 204, 205): "Ich fand zahlreiche Mitosen, deren Äquatorialplatten senkrecht auf die Längsachse des Darmes standen. Diese Theilungen lassen natürlich die Zellen des einschichtigen Epithels in ihrem epithelialen Verbande bleiben und bewirken das sehr lebhafte Längenwachsthum des Darmes. Daneben fand ich aber auch eine Anzahl von Mitosen, deren Äquatorialplatten parallel mit der Längsachse des Darmes stehen. Durch solche Theilungen muss das Epithel mehrschichtig werden, oder die eine Zelle muss aus dem epithelialen Verbande ausscheiden. Ich fand nirgends, dass das Epithel mehrschichtig wurde. Doch sah ich schon hin und wieder grosse rundliche Zellen unter dem Epithel im Bindegewebe liegen. . . . Nur an einer Stelle im Organismus fand ich Zellen, welche ich als Vorläufer von lymphatischen Zellen deuten konnte; unter dem Epithel der Darmschleimhaut und in der Umgebung des Endothelrohres der kleinsten Darmarterien fand ich rundliche Zellen mit kugligem Kern und deutlichem Plasmakörper, die besonders in Bezug auf den Kern volkommen den Darmepithelzellen glichen. Der Hauptstamm der Darmarterie zeigte solche Zellen noch nicht. Die Zellen unterschieden sich volkommen deutlich von den Bindegewebszellen, zwischen welchen sie lagen, durch Form und Grösse des Kerns. Auch fand ich nirgends im Bindegewebe Zellherde, die als Brutstätten der genannten Zellen zu deuten gewesen wären. Ebenso wenig konnte ich Mitosen an Bindegewebszellen nachweisen, die zur Bildung der erwähnten Rundzellen geführt hätten."

Choronschitzky, who studied the development of the spleen in Amphibia, reptiles and birds, agrees with Maurer that the intestinal epithelial cells migrate into the surrounding mesoderm, and give rise to mesenchyme tissues; but he states that this occurs along the whole length of the intestinal tract, and not more in the region of the spleen than elsewhere. He draws attention to the part taken by the cœlomic epithelium in the formation of the spleen (xix. p. 679): "In frühen Stadien, lange vor dem Auftreten der Milz, wo Pankreas und der Dotterdarmtractus noch nicht scharf vom Mesenchym abgegrenzt sind, kann man freilich wahrnehmen, dass von Entoderm in vom Dorsalen Pankreas, Zellen sich ablösen, und ins Mesenchym eintreten; hieraus folgt nun, dass im Mesenchym unzweifelhaft Entodermalen Elemente sich vorfinden. Sobald aber die Milz auftritt sind, das Entoderm und die daraus enstandeten Organe sehr scharf vom Mesenchym abgegrenzt. Das Mesenchym ist bereits ausgebildet; allein wie dasselbe angebildet wird, interessiert uns jetzt nicht. Es sei nur hervorgehoben, dass unzweifelhaft in demselben Elemente entodermalen Ursprungs sich finden."

Pinto does not deny Choronschitzky's view, that the proliferation of the intestinal epithelium may cause cells to wander into the surrounding mesenchyme, though he regards it as being far from satisfactorily proved. If such migration does take place, it is as frequent in other parts of the alimentary canal as in the region of the spleen, and Pinto maintains that the extruded cells become mesenchymal elements. They cannot, therefore, be regarded as forming an endodermal origin for the spleen (xxvi. p. 390). He is unable to confirm "those subtle distinctions which Maurer makes as to the varying directions of the equatorial planes of mitoses which are to be seen in the intestinal epithelium" (xxvi. p. 388).

I give here a summary in tabular form of the views taken by the different investigators as to the origin of the spleen.

1. *Endoderm.* Pancreas.	2. *Mesoderm.* Cœlomic Epithelium.	3. *Mesoderm.* Mesenchyme of Dorsal Mesentery.	4. *Endoderm.* Intestinal Epithelium.
Götte	Toldt	Peremeschko	Maurer
Schenk	Janòsik	Foster and Balfour	Choronschitzky
Kupffer	Müller	Kölliker	(indirect)
Woit	Giannelli	His	
Glas		Phisalix	
Orrù, Efisio		Laguesse	
		Stöhr	
		Minot	
		Kraatz	
		Ruffini	
		Kollmann	
		Piper	
		Tonkoff	
		Pinto.	

It will be seen from the above table that the majority of writers have taken the view that the spleen is developed from the mesenchyme, and it might seem unnecessary to go once more into the question, but it must be remembered that many of the authors quoted have only touched superficially on the question, and have dealt with the development of the spleen in different classes of vertebrates.

Tonkoff's important work deals only with the Amniota, and, in spite of Pinto's comprehensive and careful study of the question in Amphibia, Reptiles, Birds and Mammals, there still remains the fact that Maurer, and to some extent Choronschitzky, hold views which are widely different from those of other authors. It seemed worth while then, as the question, for Amphibia at any rate, is still open, to try and arrive at definite conclusions, and I therefore obtained a series of embryos of *Rana temporaria*.

In the following account the most important details of the various stages are described.

Section II. Descriptive.

My series of specimens include embryos of all stages from 10 mm. total length (4 mm. ano-buccal) to 27 mm. total length (11 mm. ano-buccal). (In older stages, the total length is no guide to the age of the embryo, and the ano-buccal length is not always dependable when the development of the limbs has begun.) I made both longitudinal and transverse sections, but found the latter the more useful. Most of them were stained in bulk with hæmatoxylin and eosin.

In an embryo of 27 mm. total length, in which the limbs have not yet appeared externally, the spleen appears as an oval body of smooth outline and of considerable size. It lies partly anterior to and partly on the left side

of the mesenteric artery, in close contact with its wall, and appears in transverse sections as if wedged between the artery and the intestine which lies on its left, and to which it is attached by mesentery (see fig. 1). It is composed of definite lymphoid tissue and contains blood-spaces, but is very uniform in its appearance. It is quite clearly separated from the artery and the intestine, and lies in the mesentery surrounded by a distinct limiting membrane.

The spleen is comparatively late in developing and its growth is

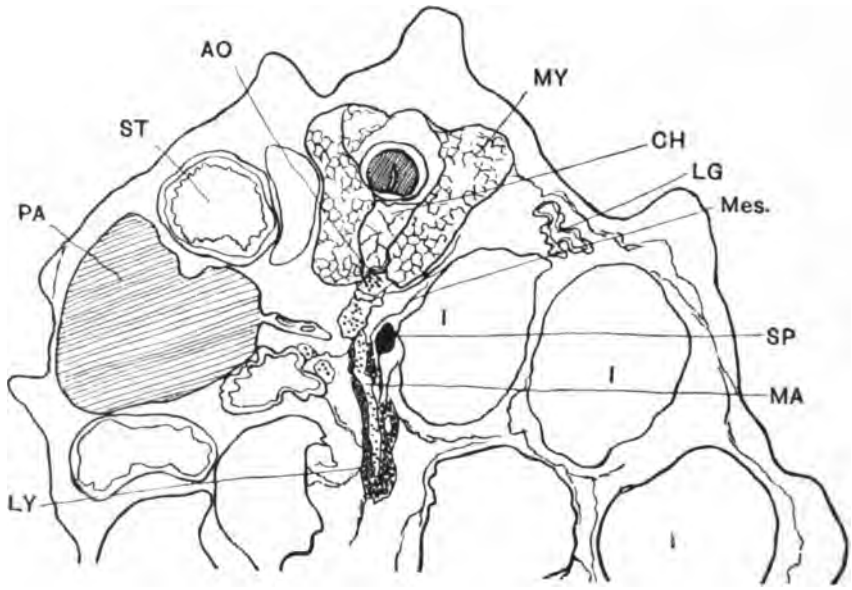


FIG. 1. Transverse section of embryo of 18 mm. total length, showing position of spleen in relation to other organs. Ventral part of section omitted.

AO, aorta; CH, notochord; I, intestine; LG, lung; LY, lymphoid cells; MA, mesenteric artery; Mes., mesentery; MY, myotome; PA, pancreas; SP, spleen; ST, stomach.

slow. Even when the limbs are well developed, the spleen shows very little advance on the condition to be seen in an embryo of 18 mm. total length.

Stage I. (fig. 2).—Embryo 10 mm. total length, 4 mm. ano-buccal. Stained methyl blue. Transverse sections of 10μ. Liver and pancreas well developed. Walls of intestine thick and convoluted. Many granulated cells containing yolk still to be found in them.

Mesenteric artery well developed, sending branches to pancreas and alimentary canal. The walls of the mesenteric artery are surrounded

throughout by a thick coat of round cells with large nuclei (PLY). These are to be seen both on the branches and on the main trunk, and already a small heaping up of such cells may be seen on the left of the mesenteric artery, exactly in the position which the spleen will later on occupy (SPA).

The cells, although not unlike the cells of the intestinal epithelium, are

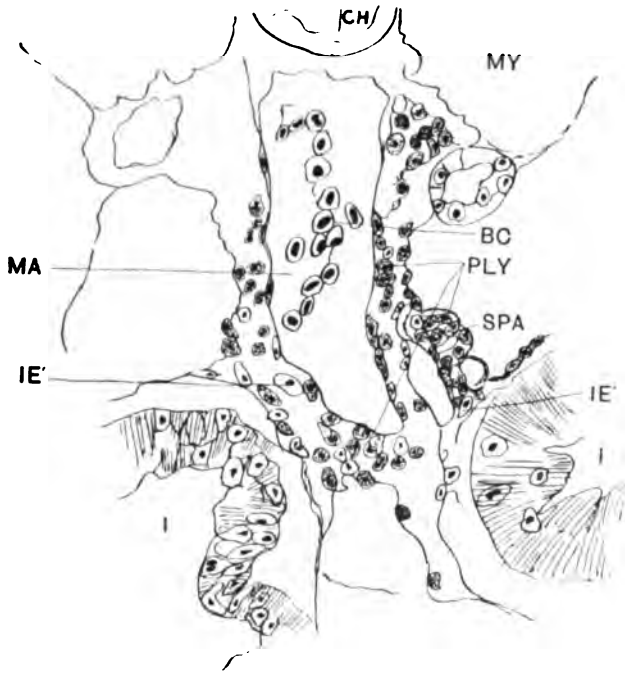


FIG. 2. Transverse section of embryo of 10 mm. total length, showing mesenteric artery with surrounding coat of lymphoid cells and the first indication of the spleen anlage. High power.

BC, blood-corpuscles; CH, notochord; I, intestine; IE', strayed endodermal cells; MA, mesenteric artery; MY, myotome; PLY, primitive lymphoid cells; SPA, spleen anlage.

not identical with them. Mitosis is certainly going on in the intestinal epithelium, but only a few of the epithelial cells show any indication of being squeezed out into the surrounding mesoderm (IE', fig. 2).

That this epithelial extrusion is not limited to early stages, nor to that part of the alimentary canal in the neighbourhood of the spleen, is shown in fig. 5, which shows such extrusion taking place. The section was taken through a part of the canal remote from the spleen, and at a stage when

the spleen was already a definite structure, covered by a limiting membrane.

In embryos of 10 mm. total length, where the spleen is in process of formation, the intestinal walls are not unistratified as in Maurer's figure, but are thick and convoluted, which makes it extremely difficult to determine in what plane mitosis takes place (fig. 2, I).

The epithelium is clearly divided in all situations from the mesenchyme lying outside it, and the round nucleated cells which are to be seen in the mesoderm among the more spindle-shaped cells are smaller and more granulated than the epithelial cells of the intestine, and resemble more closely the cells surrounding the walls of the arteries (fig. 2, PLY). Again, many of these last-mentioned cells are undergoing mitotic division, although Maurer states that no such division could be seen in the connective-tissue cells at a similar stage. They are certainly "forerunners" of lymphoid cells, and are, even at this stage, grouped as thickly around the mesenteric artery itself as round its terminal branches, even although this is an earlier stage than any described by Maurer, and there is no indication that these cells are descendants of migrants from the intestinal epithelium.

It may be objected that the cells above mentioned are not definitely lymphoid in character; but the condition I have described, and which is shown in fig. 2, persists, and the spleen is developed by proliferation of the cells, which gradually become more lymphoid in character, and surround the dorsal part of the artery at the level at which the organ is situated when it is completely established. Exactly the same kind of cells are found, as Maurer himself says, in the connective tissue of the kidney, the genital gland, etc., which could not have travelled by the same path as those followed, according to him, by the spleen cells. I quote in this connection from Pinto, who says (xxvi. p. 388), "Quello che risalta subito è il fatto che essa si presenta circondata come da una manicotto di grosse cellule rotonde con nuclei pure grossi, cellule che vanno diradandosi mano mano che andiamo verso le diramazioni arteriose che si sperdono nel mesenterio. Simili cellule troviamo anche quà e là sparse nel mesenterio ed alcune anche proprio al di sotto dell' epitelio dell' intestino."

In other embryos of 10 mm. total length the thickening of the mesenchyme cells is more general, and no definite spleen anlage can be distinguished.

Stage II.—Embryo 15 mm., stained methyl blue. Walls of intestine thinner and more simple. Single-layered epithelium shows distinct rounded body on the left side of the mesenteric artery. It is attached by mesentery to the part of the intestine lying to the left of it, and lies close against the wall of the artery. It extends through seven sections of 5μ, and

is then lost as a lymphoid thickening on the wall of the mesenteric artery. It is covered by a single layer of cœlomic epithelium, which is continuous with that reflected over the intestine and the body wall. It is in very close contact with the arterial wall, but is distinct from it. The cells are for the most part rounded, granular, with darkly stained round nuclei. They are in process of cell division, which can be seen in various stages. The tissue also contains blood corpuscles. There are no blood-spaces.

In some embryos even of slightly greater length the spleen is less definite. The lymphoid tissue is present in large quantity, and is heaped up around the artery at the level where the spleen eventually comes to lie. In one series of sagittal sections the splenic thickness is very well marked, and the mesenteric artery passes through its posterior part. This is probably due to the fact that the spleen is closely associated with the lymphoid tissue surrounding the wall of the artery, and occasionally extends backwards into closer connection with it. The same remarks concerning the character of the cells apply as in the last stage described.

Scattered cells are to be seen which appear to be identical with the endodermal epithelial cells, and may have been extruded in the process of cell division, but they are quite casually distributed, and the difference between them and the lymphoid cells is clearly marked (fig. 5).

Embryo 18 mm. total length. Stained hæmatoxylin and eosin. The spleen runs through nine sections of 10μ. It is considerably more definite than in the last stage, and lies freely in the mesentery, though in very close contact with the wall of the artery, which is still surrounded by scattered lymphoid cells, and with the part of the intestine which lies to its right. The cœlomic epithelium covers the free surface, but there is not a definite capsule (fig. 1, SP).

The cells composing it are already definitely lymphoid in character (fig. 3, LY). As compared with those of the intestinal epithelium, they differ markedly from the latter, being smaller, more irregular, and inclined to be elongated in shape and more granular, the protoplasm taking a deeper stain, while the nucleus is more diffuse. At this stage mitosis is still proceeding in the cells of the intestinal epithelium, but it is difficult even yet to determine the plane of division on which Maurer lays so much stress (fig. 3, IE). Here and there, cells derived from these mitotic divisions lie outside the basement membrane in the mesenchyme surrounding the intestinal wall. They are also to be seen here and there along the walls of branches of the mesenteric artery, but they do not collect specially round its terminal branches, as Maurer asserts, and they appear to be quite distinct from the lymphoid cells on the arterial wall, which are to be seen in the same sections. A certain amount of emigration from the

intestinal epithelium does take place, but there seems no reason for believing that the cells which have migrated take any direct part in the formation of the spleen.

Stage III.—Embryo 24 mm. Sagittal section. Stained hæmatoxylin and eosin. The spleen runs through eighteen sections of 10μ; it lies against the wall of the mesenteric artery, to the left side of and anterior to it. It is surrounded by a capsule of flattened epithelium, and is separated from the artery wall. It is dorsal and posterior to the stomach.

The cells are granulated, the majority are rather large and rounded, and the epithelial capsule is incomplete. Various stages of cell division can be seen in the splenic cells, many blood corpuscles are scattered through the

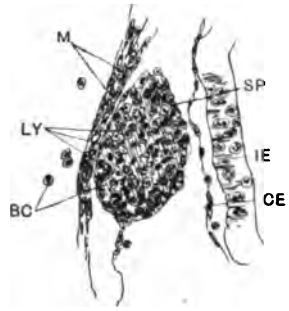


FIG. 3. Spleen in embryo of 18 mm. total length, lying between wall of mesenteric artery and wall of intestine. High power. Lymphoid cells of the spleen in various stages of division.

BC, blood-corpuscles; CE, cœlomic epithelium; IE, intestinal epithelium; LY, lymphoid cells; M, primitive muscle fibres; SP, spleen.

tissue, and some dark elongated cells are present, which often divide transversely.

Embryo 27 mm. total length, 11 mm. ano-buccal. Stained hæmatoxylin and eosin (fig. 4). Shows the spleen as an oval, smooth body, running through thirty-five sections of 10μ. It lies freely in the dorsal mesentery, by the side of the mesenteric artery. At its greatest diameter it is in very close contact with the artery, and with the intestine to the left of it, but it is separated from it, both by the cœlomic epithelium and by its own distinct limiting membrane. In some sections a small blood-vessel is seen running between the intestine and the spleen, and sending branches into it. The dorsal mesentery is very diffuse and thin, and shows many sections through blood-vessels. Cells consist of (1) large cells with granular

nuclei in various stages of cell division; some are rounded, others spindle-shaped or oval. (2) Smaller elongated cells, very deeply stained; these are possibly blood corpuscles in an imperfect state. (3) Red blood corpuscles (see fig. 4). In some sections small vessels can actually be seen entering

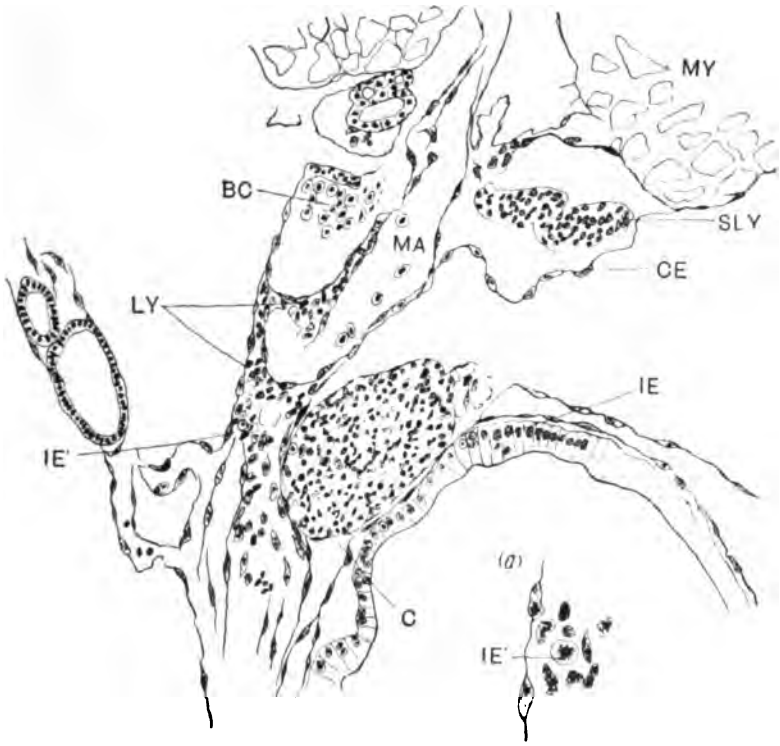


FIG. 4. Transverse section of embryo of 27 mm. total length (11 mm. ano-buccal), showing spleen, mesenteric artery with lymphoid cells around its walls, and intestinal epithelium. (*a*) A small portion of mesentery near the arterial wall, showing a wandered cell from the intestinal epithelium among the mesenchyme cells.

BC, blood-corpuscles; CE, cœlomic epithelium; IE, intestinal epithelium; IE', strayed endodermal cells; LY, lymphoid cells; MA, mesenteric artery; MY, myotome; SLY, subchordal lymphoid tissue.

the spleen tissue. There are no definite Malpighian corpuscles, but the whole tissue is permeated with blood corpuscles.

In an embryo in which the limbs were well developed and the tail partly absorbed, the spleen shows very little further advance in structure, but the capsule is rather more developed. It will be seen from fig. 4 that the lymphoid tissue which surrounds the artery is less dense than in

earlier stages of development, and is more conspicuous around the main trunk of the artery than at its terminal branches. The lymphoid mesenchyme cells (LY, fig. 4) around the artery are exactly similar to those in the spleen itself, and differ markedly from the cells which appear to be strayed endodermal cells from the epithelium of the alimentary canal.

In fig. 4 there are a few of these cells (IE′) to be seen lying in the mesentery among the mesenchyme cells. It will be seen that they differ in appearance from the latter, while they bear a strong resemblance to the cells of the intestinal epithelium, being large, clear, and spherical in shape, with very definite nuclei.

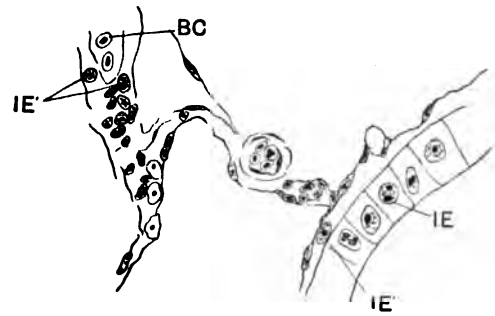


FIG. 5. From an embryo of 15 mm. total length. Portion of intestinal wall, with small terminal branch of mesenteric artery and mesentery. White and red blood-corpuscles, mesenchyme cells in the mesentery, and strayed endodermal cells. One cell from the intestinal epithelium lies between it and the epithelium of the mesentery.

BC, blood-corpuscles; IE, intestinal epithelium; IE′, strayed endodermal cells.

In the same series of sections, similar cells are to be seen lying in the mesentery in parts of the alimentary canal remote from the spleen, and they appear to be quite impartially, though sparsely, distributed.

The first possible forerunners of the lymphoid cells of the spleen are then to be found in embryos of 10 mm. total length (about 4 mm. ano-buccal). The mesenteric artery at this stage has a thick coat of mesenchyme cells, which have begun to be heaped up in the position to be occupied by the spleen. These cells are grouped thickly round the main trunk and branches of the mesenteric artery, and in no instance did I find such cells surrounding the terminal branches, and not the artery itself. These cells differed in appearance from those of the intestinal epithelium in size, shape, and appearance of nucleus. Cells identical with the intestinal epithelium

were to be seen here and there in the mesentery, but were few in number, and easily to be distinguished from the mesenchyme cells among which they lay (fig. 4, (*a*)). In no case were there such cells in the spleen anlage itself, nor was there any transition stage which could lead me to suppose that they were altering their character. The appearance of the above-mentioned cells, both in the mesentery and in the mesenchyme surrounding the intestine, confirm Maurer's view that there is a migration of intestinal epithelium, but the migration takes place along the whole length of the intestinal canal, and continues long after the spleen is a distinct structure and the cells take no part in spleen formation.

The cells were more frequent in the later stages than in the less developed embryos, and even at the stage at which Maurer first notes their appearance the spleen anlage has begun to appear.

Even before there is any trace of the actual spleen, the trunk of the mesenteric artery shows the thick coat of mesenchyme cells, which are undoubtedly primitive lymphoid tissue.

The cœlomic epithelium certainly forms the capsule, but it does not appear to take a larger share than this in the development of the spleen. The limiting membrane is very distinct from the rest of the tissue throughout its development. (See Laguesse, x. p. 476.)

Conclusions.

In the first place, it may be stated that the pancreas, in Rana at least, can have no part in the formation of the spleen. The two organs are not in contact at any stage in the development of either, and the pancreas is already well developed when the spleen "anlage" first appears.

Secondly, for reasons which I hope I have made clear in the last section, I do not believe that the endodermal epithelium of the intestine is responsible for the formation of the spleen, even indirectly. The migration of cells from the intestinal epithelium, where it does occur, takes place at a stage when the spleen "anlage" is already formed, and when the cells of which it is composed are themselves proliferating rapidly. However, that these epithelial cells do go to increase the mesodermal tissue of the mesentery seems clear, though I do not think the part they play is a very considerable one.

My conclusion then is, that the spleen in Rana arises from the mesenchyme tissue of the dorsal mesentery, in close connection with the mesenteric artery, as a thickening of the lymphoid tissue which surrounds the wall of the artery at an early stage. It develops by proliferation and differentiation of these primitive lymphoid cells, and becomes highly

vascular. The cœlomic epithelium appears to form the capsule, and perhaps enters into the formation of the reticular network.

In conclusion, I must express my gratitude to Professor Robinson for his most kind assistance and criticism, and for placing the necessary apparatus at my disposal while I was working in the Anatomical Department at Birmingham University. My warmest thanks are also due to Dr Violet Coghill, whose constant help and suggestion have been invaluable.

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THE COMPARATIVE ANATOMY, GROSS AND MINUTE, OF THE THYROID AND PARATHYROID GLANDS IN MAMMALS AND BIRDS.

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PART II.

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III.—AVES.

THE number of birds in which the condition of the thyroid and parathyroid was investigated was thirty-five, including thirty-four different species. The series comprised examples of most of the important orders, namely, Passeriformes, Columbiformes, Psittaci, Raptores, Herodiones, Alectorides, Galliformes, Limicoliformes, Pygopodiformes, Lamellirostes, Crypturi, and Struthiones.

The broad result of these investigations is to show that the thyroid and parathyroid of birds agree generally with those structures in mammals, but they also present certain points of contrast. Before considering these in detail it is necessary to anticipate somewhat by stating that, as with mammals so with birds, it has sometimes been difficult to decide whether a

particular gland was to be regarded as a thyroid or parathyroid. Each of these in its typical appearance is of course readily identified, but the two structures are so often intermixed that it is not always easy to settle which name to give to the whole. A few examples will illustrate this difficulty. The anatomical thyroid of the Californian Quail was found to be wholly parathyroid in nature. In the Barn Owl only the cortex of the thyroid possessed thyroidal structure: the deeper parts were typically parathyroidal. In the Gray Parrot, the Oyster-Catcher, and other birds the anatomical parathyroid was directly continuous with the thyroid, no connective-tissue septum being interposed, so that the whole formed a single gland.

The inferences which must be drawn from these and other facts will be considered in detail in a subsequent paper (6), when the nature of the parathyroids and their relation to the thyroid is discussed; but it is desirable to retain here, as in the section devoted to mammals, the two terms thyroid and parathyroid in their usually accepted meaning as expressing the vesicular and non-vesicular glands respectively. The method of identification followed in this section will be to style as thyroid those glands which possessed the naked-eye anatomical features and relations of a thyroid gland, irrespective of their histological details; to include under the heading of accessory thyroid those smaller and more variant glands whose structure was wholly or chiefly vesicular; to identify as parathyroid those smaller glands whose histological features agreed wholly or chiefly with those of a parathyroid; and lastly, to reckon as a parathyroid the non-vesicular posterior extremity of a vesicular thyroid even though the two were directly continuous.

General Observations on the Thyroid and Parathyroids in Birds.

1. *Position, Form, etc., of the Thyroid.*—The thyroid in birds never lies, as in the case of mammals, in contact with the trachea, its most intimate and constant relations being with the carotid artery and jugular vein. On reflecting the skin, the glands must be sought at the root of the neck partly sheltered by the sternum. The left lobe, as a rule, lies attached to the ventral aspect of the left carotid artery external to the trachea and œsophagus, internal to the jugular vein, and at a level anterior to the syrinx. The right lobe is, as a rule, at the same level as the left, and is attached to the ventral aspect of the right jugular vein external to the carotid artery and trachea. These situations are not invariable, for either lobe may lie on the jugular vein, on the carotid artery, between the vein and artery, external to the vein or internal to the artery. They are, however, always in the immediate neighbourhood of these vessels.

The thyroid is of a rich, reddish-brown colour, and it is generally somewhat translucent. Its shape is globular, and if one axis exceed the other, the longer runs more or less antero-posteriorly, rarely transversely. The lobes may be partially screened from view by fat, and though often of equal size, one or other may be the larger. The actual size depends to a great extent, of course, on the particular bird examined—in the Ostrich they were the size of a plum, in the Herring Gull that of a small pea.

2. *Position, etc., of the Parathyroids.*—In the majority of cases the number of parathyroids is limited to one on each side, lying in contact with the thyroid at or near the posterior pole. In a few specimens the parathyroid is bilobed, while occasionally two separate parathyroids occur. When this last condition holds it is frequently found that the glands are some little distance remote from the thyroid usually posterior to it, but possibly dorsal, discoverable only after removal of the thyroid. Most parathyroids are oval or spherical in shape, and their colour is white or yellow without any translucency. They cannot be distinguished by the naked eye from lymphatic glands. Like the thyroid, their size varies with that of the species, but it is usually very much smaller indeed than the thyroid, though it may be almost half the size of the latter.

3. *Structure of the Thyroid.*—As the mammalian gland so the avine is divided into compartments by connective-tissue trabeculæ arising from a thin capsule. Each compartment contains a vesicle generally well filled with homogeneous colloid and lined by flattened epithelial cells. Not uncommonly these cells are intermediate between flattened and cubical (*i.e.* a squat cubical), but they may be cubical or very rarely columnar. In most sections the majority of the follicles are lined by the pavement variety, but some composed of squat cubical cells are almost certain to be found. The vesicles are very closely packed, as the trabeculæ are delicate, and interstitial cells are wholly wanting, or present to a very limited number. When present they occur either isolated or in small or large groups, and such cells are not to be distinguished from parathyroid cells. They will be referred to as interstitial or parathyroid cells.

Owing to these characters — the flattened epithelial cells and the absence of all but the slightest intervesicular structure—the avine thyroid is sufficiently distinctive and can, as a rule, be distinguished from a mammalian thyroid.

4. *Structure of the Parathyroids.*—These glands possess a connective-tissue framework similar to that of the thyroid. The compartments, however, are filled with solid masses of polyhedral cells without any follicular formation. Occasionally the cells show an attempt to group themselves around a central lumen, in which case a primitive vesicle results,

and not rarely perfectly formed follicles are found. The protoplasm of the cells show the same variations in activity and rest as has been described in mammalian parathyroids. On the whole, the parathyroids of birds are more often inactive than those of mammals.

Colloid may be present not only in the vesicles, but also as drops between the parathyroid cells.

5. *Intermediate Types.*—With a frequency which was quite unexpected, thyroid glands were found which contained genuine parathyroid tissue. This varied in amount. There might be only a few interstitial or parathyroid cells lying between the vesicles, or the cells might be in small clumps. In some instances whole fields were exclusively parathyroid, and in one instance the entire thyroid was without any vesicles, consisting throughout of true parathyroid tissue. In all cases where both types of structure were present there was no separation between the two—the one merged into the other, so that it was impossible to draw any line of separation.

Similarly, parathyroids attached to the posterior pole of the thyroid would often be continuous with the main gland.

The small accessory glands in the neighbourhood of the thyroid often showed the same intermediate types between pure thyroid and pure parathyroid.

Note.—In the pages that now follow will be found detailed accounts of the thyroid and parathyroid in each bird examined. These descriptions must necessarily be to some extent repetitive, but to reduce this defect to a minimum, details of position and structure are given only when they differ from those already noted as typical. In other cases the descriptions have not been set out at length, but are expressed by such terms as "thyroid in usual position," "parathyroid normal." On these occasions it is to be understood that the condition thereby indicated agrees with that mentioned above as obtaining in most specimens.

It remains to mention that certain of the birds had been skinned before reaching my hands, and in some of these I found that the thyroid or parathyroid on one side had been cut away. Mention is made of this accident under the name of the injured bird.

Passeriformes.

Of the four members of this order examined, three—the Cardinal Grosbeak, the Common Mynah, and the Larger Hill Mynah—had one parathyroid on each side, and one—the White-backed Piping Crow—had two on one side. The thyroid of this last bird was peculiar in that it

contained more parathyroid than thyroid tissue, and in that intermediate types where the cells had formed only imperfect vesicles were readily found.

WHITE-BACKED PIPING CROW (*Gymnorhina leuconota*). (Age at least 1 year.)

Thyroid.—Right was in the usual position and showed deep to it two yellow-coloured parathyroids.

Left had been cut away in process of skinning. Deep to it lay one yellow parathyroid.

Microscopical Appearances.—The specimen was an interesting one. The thyroid was made up of more parathyroid than thyroid tissue. For the most part the cells, parathyroid in appearance, were arranged in masses with no attempt at vesicle formation. In places there were obvious attempts at the regular formation of the cells around a central cavity. In other situations the vesicular formation was complete, and definite thyroid tissue was to be seen lined by regular cubical epithelium and containing colloid.

The parathyroids presented the customary features.

CARDINAL GROSBEAK (*Cardinalis virginianus*).

Thyroid.—Right in usual position, with a special vessel running to its anterior end and a parathyroid attached to its posterior.

Left at usual level in neck, but lay lateral instead of ventral to the carotid artery. A parathyroid was attached to its posterior pole.

Microscopical Appearances.—Both thyroid and parathyroid conformed to the usual types in birds.

COMMON MYNAH (*Acridotheres tristis*). (Age at least 1 year.)

Thyroid.—Right lay on the ventral surface of the carotid artery. No parathyroid was attached to it, but a short distance behind the posterior pole, dorsal to the artery and ventral to the vein, was a small yellow parathyroid.

Left corresponded in position to its fellow, but its parathyroid was closer to the thyroid than on the right but was not in actual contact.

Microscopical Appearances.—The thyroid was made up of vesicles of varying sizes, the majority containing colloid; but some were empty, and a few enclosed a pale granular material. In those areas where the vesicles were smallest there was a certain number of parathyroid cells, but they were absent among the larger vesicles.

The parathyroids as usual.

LARGER HILL MYNAH (*Grœcula intermedia*). (Age at least 3 years.)

Thyroid.—Right was placed lateral to the carotid artery, its parathyroid lying median to it in close association with a lymphatic gland.

Left lay in contact with the median aspect of the carotid artery, its parathyroid being removed a short distance back and lying near a small lymphatic gland.

Microscopical Appearances.—Both thyroid and parathyroid presented the usual features. There were a few parathyroid cells in the thyroid.

Columbiformes.

The single representative of this order was the Scaly Ground Dove (Pl. II. fig. vii.).

Scaly Ground Dove (*Scardafella squamosa*).

Thyroid.—Right lay on jugular vein and vagus nerve just anterior to the bifurcation of the carotid artery. It was ovoid in shape, the long axis being directed anteroposteriorly. No parathyroid was appended to the posterior pole, but a short distance farther back one was found in the interval between the carotid artery and the jugular vein.

Left lay on the ventral surface of the external branch of the carotid artery just anterior to its bifurcation, its form and the direction of its axis being as on the right side. A parathyroid was attached to its posterior pole. The jugular vein and vagus nerve ran external to both thyroid and parathyroid.

Microscopical Appearances.—Both glands presented the usual features, but perhaps there were more interstitial cells in the thyroid than normal.

Psittaci.

Four examples of the Parrot tribe were examined.

The Pale-headed Paroquet had two parathyroids on the right and one on the left; the Gray Parrot two on the left and at least one on the right; the West African Love-Bird (Pl. II. fig. v.) a single bilobed parathyroid on the right and two parathyroids on the left. In the first-named bird a few drops of colloid were found on the surface of one parathyroid, while in the Gray Parrot one parathyroid was directly continuous with the thyroid without the intervention of any connective-tissue partition. The Love-Bird showed the same continuity of the two structures, but in this case thyroid vesicles reappeared at the free end of the parathyroid; that is to say, the thyroid proper gave place near one pole to parathyroid tissue, and this again at the extreme pole to thyroid tissue. The Purple-capped Lory had one parathyroid on each side.

Pale-headed Paroquet (*Platycercus pollidiceps*). (Age at least 8 months.)

Thyroid.—Right lay between and ventral to the carotid artery and jugular vein at the level where the œsophagus crossed ventral to the trachea. It was translucent in appearance and showed a white parathyroid at its posterior pole. Another parathyroid was disclosed on microscopic examination on the surface of the thyroid (v. i.).

Left lay at the same level but on the carotid artery, its long axis being more oblique than that on the right. A white parathyroid was attached to its posterior pole.

Microscopical Appearances.—The thyroid showed the usual structure, as also did the parathyroid. On the surface of one of the latter, however, there were two or

three drops of colloid secretion. There was a delimiting zone of connective tissue between the parathyroid and its secretion and the thyroid.

GRAY PARROT (*Psittacus erithacus*).

Thyroid.—Right had been cut away when the bird was skinned, but at the level, where it had presumably been, was found a parathyroid.

Left lobe was placed in the usual position, and on its postero-external part was an opaque white parathyroid and posterior to it another very small parathyroid more translucent-looking than the first.

Microscopical Appearances—The thyroid had its usual appearance, and nearly all its vesicles were lined by flattened epithelium. One of the parathyroids was directly continuous with the thyroid without the intervention of any connective tissue. The two formed one gland, and had the usual features. Some lymphoid tissue lay on the surface of the parathyroid.

WEST AFRICAN LOVE-BIRD (*Agapornis pullaria*). (Age at least 3 years.)

Thyroid.—Left lay on the jugular vein lateral to the carotid artery, with a bilobed parathyroid at its posterior pole.

Right was about the same level as the left on the ventral surface of the jugular vein and carotid artery, exactly where in this specimen the latter crossed the former. It was the size of a pin's head. A parathyroid was found at its posterior pole, and less than 1 cm. posterior to this a second parathyroid came into view.

Microscopical Appearances.—The thyroid was made up of small, regularly formed vesicles lined by squat, cubical epithelium and filled with homogeneous colloid. The parathyroid at the posterior pole was directly continuous with the thyroid tissue, no connective tissue intervening. The parathyroids were divided by connective tissue into compartments containing the usual cells and also clear spaces (? fat). The extreme pole of the parathyroid continuous with the thyroid presented a reappearance of typical thyroid tissue.

PURPLE-CAPPED LORY (*Lorius dormicella*). (Age at least 2 years.)

Thyroid.—Right—an elongated body tapering towards its anterior pole, with a small white parathyroid at the posterior pole—lay on the carotid artery between the jugular vein and the œsophagus, which in this specimen curved over to the right of the trachea.

Left was an elongated and translucent body lying ventral to the jugular vein and vagus nerve, attached to the dorso-lateral margin of the carotid artery. A very small white parathyroid clung to its posterior pole.

Microscopical Appearances.—The thyroid showed all the customary features except that the cells were cubical, and there was a number of interstitial or parathyroid cells scattered through each field. The parathyroids were normal.

RAPTORES.

Examination was made of ten species of this order, including examples of the Falcones, Sarcorhamphidæ, Syrniinæ, and Strigidæ.

In the Angolan Vulture, the Kestrel (Pl. II. fig. viii.), and the Egyptian Kite one parathyroid on each side was found. In the South African

Kestrel, the Short-toed Eagle, and the Elenora Falcon, where the examination was unavoidably restricted to one side of the neck, the numbers found were two, one, and none respectively. The Condor Vulture presented no parathyroid on either side, but in the Kite there were two on one side and one on the other, the latter being exceptionally large.

It may be noted that whereas in some of these birds of prey the parathyroid on each side was single, in the Short-toed Eagle and the Egyptian Kite the parathyroid was bilobed but still single, while in the South African Kestrel the lobulation had divided the gland completely into two. One of the parathyroids of the Angolan Vulture contained a number of large drops of colloid in the intercellular spaces. Sections of the thyroid of the Elenora Falcon showed a complete absence of vesicles, all the compartments being occupied by masses of polygonal cells while the lymphatics were filled with colloid secretion.

The family of Syrniinæ was represented by the Long-eared Owl, and the Strigidæ by the Barn Owl. In both there was a single parathyroid attached to each thyroid lobe. In the Long-eared Owl (Pl. II. fig. vi.) both thyroid and parathyroid tissue were directly continuous, while in the Barn Owl the superficial parts of the thyroid were made up of vesicles, the central areas being similar in structure to the parathyroid.

ELENORA FALCON (*Falco elenoræ*). (Age at least 4 years.)

Thyroid.—Right was in usual position, but no parathyroid could be found.

Left had been cut away with the skin.

Microscopical Appearances.—Sections of the gland showed a remarkable appearance. There was nowhere any vesicular formation. The whole gland was divided into compartments by delicate but distinct trabeculæ. Each compartment was filled with polyhedral cells which were large and varied in shape according to the pressure of surrounding cells. Each possessed a nucleus, small and dark-staining, surrounded by a considerable amount of granular protoplasm staining readily with eosin.

Scattered uniformly through the section, but most frequent at the surface, were collections of colloid. None of these was found among the polyhedral cells themselves, but all were contained in the lymphatic spaces supported by the trabeculæ. The collections varied in size and for the most part were stellate in outline, their processes passing along the connective tissue between adjoining compartments.

The general appearance was that of a gland—from its anatomical characters obviously a thyroid gland—whose colloid secretion, instead of passing first into the central lumen of a vesicle and so away by the lymphatics, drained from each cell direct to a small lymphatic.

SHORT-TOED EAGLE (*Circaëtus gallicus*). (Age at least 1 year.)

Thyroid.—Right lobe had been cut away with the skin.

Left lobe in usual position, globular in form, with a bilobed parathyroid at the posterior pole.

Microscopical Appearances.—The vesicles of the thyroid were lined for the most part with flattened cells and filled with homogeneous colloid. A few interstitial cells, but not many, lay between the follicles. Parathyroid normal.

ANGOLAN VULTURE (*Gypohierax angolensis*).

Thyroid.—Each thyroid lay between the carotid artery and jugular vein of its side but was placed somewhat ventral to them.

Both parathyroids were detached from the thyroids. The left was 1 cm. posterior to the lobe, the right ·5 cm. posterior.

Microscopical Appearances.—Thyroid as usual. There were no interstitial cells and the lining cells were squat cubical or flattened. The vesicles contained much colloid.

The parathyroids were of usual structure, but the special point of interest in one of them was the presence of half a dozen or more large drops of colloid between the cells not enclosed in definite vesicles.

EGYPTIAN KITE (*Milvus ægyptius*). (Age at least 7 years.)

Thyroid.—Right in usual situation, with a parathyroid at the posterior pole. Deep to the thyroid was a greenish-white translucent body—a cyst.

Left, as usual, with a bilobed parathyroid at the posterior pole.

Microscopical Appearances.—Thyroid vesicles were lined by squat, cubical cells. There were no interstitial cells.

The parathyroids showed the usual continuous mass of cells.

COMMON KITE (*Milvus ictinus*). (Age at least 11½ years.)

Thyroid.—Right appeared at the usual position. Just anterior to its anterior pole, but not in contact with it, lay two small opaque white bodies which proved to be lymphatic glands. It was only after removal of the thyroid that a parathyroid, almost half the size of the thyroid and of similar macroscopic appearance, was discovered lying between the carotid artery and jugular vein and distant from the thyroid quite ·5 cm.

Left lay in the customary site on the carotid artery, but placed somewhat to its inner side. There was no parathyroid in contact with the lobe, but on the external side of the carotid artery two small yellowish-white parathyroids were found.

Microscopical Appearances—The thyroid had the typical structure, practically all the cells being flattened. The surface of the colloid was scolloped, but this was probably factitious.

Parathyroids normal.

KESTREL (*Tinnunculus alaudarius*). (Age at least 1 year.)

Thyroid.—Right lay on the ventral surface of the carotid artery and vagus nerve, internal to the jugular vein, its long axis being directed back and in. A parathyroid was attached to the posterior part of its lateral surface.

Left lay on the ventral surface of the carotid artery, its axis directed as on the right side, the anterior pole just touching the jugular vein. A parathyroid occupied a corresponding position to that on the right.

Microscopical Appearances.—The thyroid was composed of regular vesicles lined

by short cubical cells and filled with homogeneous colloid. There were few or no interstitial cells.

The parathyroids showed the usual structure.

South African Kestrel (*Tinnunculus rupicolus*). (Age at least 18 months.)

Thyroid had been cut away with the skin on one side, but on the other was present in the usual position with a bilobed parathyroid at its posterior pole.

Microscopical Appearances.—Post-mortem changes were too marked for reliable details of the microscopic appearances of the glands. The parathyroid, however, was completely divided into two by a septum of connective tissue.

Condor Vulture (*Sarcorhamphus gryphus*).

The thyroid glands occupied the usual positions. No parathyroid was found.

Microscopical Appearances.—The thyroid presented the usual features, with a few interstitial cells between the vesicles.

Long-eared Owl (*Asio otus*).

Thyroid.—Right was attached to the ventral surface of the carotid artery at the level where the latter crossed ventral to the jugular vein. Pendent from its posterior pole was a parathyroid.

Left rested on the ventral surface of the jugular vein, in contact with the lateral aspect of the carotid artery. A parathyroid was attached to its posterior pole.

Microscopical Appearances.—The thyroid was composed of regular vesicles lined with cubical epithelium and containing colloid. There were no interstitial cells between the follicles.

The parathyroid tissue proper was in direct contact with the thyroid tissue without any intervening stroma. It presented the usual appearance, being compartmented by connective tissue the meshes of which were filled with clusters of cells arranged without order.

Barn Owl (*Strix flammea*). (Age at least 11 months.)

Thyroid.—Each lobe occupied the usual position, with a parathyroid attached to the lateral aspect of the posterior pole.

Microscopical Appearances.—The superficial parts of both thyroid glands showed regular vesicles lined by short cubical epithelium, many (but not the majority) containing colloid. In these regions there were no interstitial cells. The more central areas of the gland contained but few vesicles, the cells being for the most part massed in irregular clusters.

The parathyroids showed a structure in every way similar to the central parts of the thyroid.

Herodiones.

In this order representatives were examined of the families of Ardeidæ Ciconiidæ, and Ibididæ. The Night Heron possessed one parathyroid on each side, but both were bilobed. In the Maguari Stork (Pl. II. fig. i.) one parathyroid was found on each side, and in the American Jabiru none was

found, though in this last the dissection was unavoidably limited to one side. Of the two examples of White Ibis the first (Pl. II. fig. iii.) had one parathyroid and one accessory thyroid on each side, the second (Pl. II. fig. ix.) two parathyroids on each side.

NIGHT HERON (*Nycticorax griseus*). (Age at least 6 years.)

Thyroid in usual position. The parathyroid, which was attached to the posterior pole of each lobe, was distinctly bilobed.

Microscopical Appearances.—Thyroid vesicles lined by flat or squat cubical cells. No interstitial cells.

Parathyroids normal.

MAGUARI STORK (*Dissura maguari*).

The thyroid lobes, which were flatter and less globular than in most birds, lay on each side against the ventral aspect of the carotid artery,[1] internal to the jugular vein, but each was considerably overlapped by an elongated mass of lymphoid tissue running along the neck. Each of these masses terminated posteriorly in a parathyroid gland.

Microscopical Appearances.—Thyroid structure normal. No interstitial cells.

Parathyroids normal.

AMERICAN JABIRU (*Mycteria americana*). (Age at least 2 years 4 months.)

The thyroids were in the usual position, but showed no parathyroids at their posterior poles. On the left side, lying on the carotid artery, 1 cm. posterior to the thyroid, were two small glands, the anterior being the larger. Unfortunately they were lost before being sectioned. No corresponding bodies were found on the right side.

Microscopical Appearances.—The thyroid presented points of interest. It was made up of vesicles of varying size, none very small, few very large, and all, with scarcely any exception, filled with homogeneous colloid. The majority of the lining cells were of the pavement variety, but it was not uncommon to find a lining of cubical cells. In the largest follicles the epithelium presented an irregular, broken appearance, owing to the projection of large tall cells filled with granular protoplasm. The interstitial or parathyroid cells were present to a greater number than in any other avine thyroid examined. They occurred in groups large and small, and were pretty evenly distributed through every field.

WHITE IBIS (*Eudocimus albus*). (Age 3 years 7 months.)

Specimen No. 1.—On dissection large masses of lymphoid tissue were found in the neck, all of which showed marked degenerative changes in their centres. These masses were enlarged tuberculous glands.

Thyroid —Right lay on the ventral surface of the jugular vein, well external to the carotid artery. A parathyroid touched its posterior pole.

Left was bound to the ventral surface of the carotid artery. Its parathyroid corresponded in position to that on the right.

[1] In the figure the left carotid artery runs too near the middle line.

On each side an accessory thyroid was found. On the right it was a minute gland less than a pin's head in size, lying under shelter of the clavicle; on the left it was even smaller, and lay on the ventral surface of the carotid artery about 2·5 cm. anterior to the thyroid.

Microscopical Appearances.—Sections of the thyroid presented a uniform appearance of vesicles lined by cubical epithelium and filled with colloid. There were few or no interstitial cells.

Parathyroids normal.

Specimen No. 2 (age 11 months).—*Thyroid.* Right was discovered at the usual level, but lay between the carotid artery and jugular vein, closer to the former than to the latter. A short distance posterior, and connected to it by a process, were two parathyroids.

Left lay on the carotid artery, with two parathyroids a short distance posterior to it.

Microscopical Appearances.—Thyroid structure as usual, but contained some clusters of interstitial cells.

The parathyroids were composed of the usual masses of cells. The process connecting the right parathyroids to the thyroid was of lymphoid tissue.

Alectorides.

One specimen each of the families of Gruidæ and Rallidæ were examined. The Crowned Crane (Pl. II. fig. x.) had two parathyroids on each side posterior to the thyroid; the Indian Porphyrio one on each side, that on the left being trilobed.

Crowned Crane (*Balearica pavonina*). (Age at least 1 year.)

The thyroids lay on the ventral aspect of the carotid arteries. No parathyroids were at their posterior poles, but a pair were found a little distance posterior on each side. They lay close against the carotid artery on the right; on the left between the artery and the jugular vein.

Microscopical Appearances.—The follicles of the thyroid were lined by flat or squat cubical cells and contained homogeneous colloid. No interstitial cells were present.

Parathyroids normal.

Indian Porphyrio (*Porphyrio calvus*). (Age at least 2 years.)

Thyroids as usual. The left was considerably larger than the right. A parathyroid was present on each side, but not in contact with the lobe. On the right it was 3 mm. posterior to the thyroid, and on the left dorsal to it, being discovered as a trilobed body only after removal of the thyroid.

Microscopical Appearances.—No feature of special interest in either thyroid or parathyroid.

Galliformes.

This order is represented by two birds of the family of Tetraonidæ.

Both the Californian Quail and the Virginian Colin showed one para-

thyroid to each thyroid lobe, but whereas in the latter the thyroid was vesicular, in the former follicles were entirely absent and the gland had the structure of a parathyroid.

CALIFORNIAN QUAIL (*Callipepla californica*). (Age at least 10 months.)

Thyroid.—Both glands filled the usual position and were closely attached to the great vessels. At the posterior pole of each was a small parathyroid.

Microscopical Appearances.—The thyroid had no thyroid attributes. It was made up of connective-tissue compartments, each of which contained a cluster of polyhedral cells without any trace of colloid or vesicle formation.

The parathyroids were similar in structure.

Had it not been that the specimens were kept apart throughout their preparation, it would not have been possible to recognise which was thyroid and which parathyroid.

VIRGINIAN COLIN (*Ortyx virginianus*). (Age at least 4 years.)

Thyroid.—Both occupied the usual position. The left showed in contact with its posterior pole a small white parathyroid, while on the right this gland lay sunk in the middle of the ventral surface of the lobe.

Microscopical Appearances.—The thyroid presented no unusual feature unless it were that more vesicles than customary in birds were lined by cubical epithelium and fewer with flattened cells.

Parathyroids normal.

LIMICOLIFORMES.

The two examples of this order were from the families of Charadriidæ and Laridæ.

The Oyster-Catcher was without any isolated parathyroid, but the posterior pole of each thyroid lobe was pale yellowish-white in colour, and was composed of parathyroid tissue directly continuous with the thyroid proper. In the Herring Gull (Pl. II. fig. ii.) there was one parathyroid on each side.

OYSTER-CATCHER (*Hæmatopus astralagus*). (Age at least 7 years.)

Thyroid lobes were in the usual position, but no separate parathyroid was seen on either side. Each lobe, however, showed a pale, yellowish-white area at its posterior pole, which proved to be parathyroid in structure. The right, in addition, presented a similar area near the anterior pole, but under the microscope this was identified as lymphoid tissue.

Microscopical Appearances.—The thyroid had the usual structure, with a small number of interstitial cells. The pale area at the posterior pole was typical parathyroid tissue, but was directly continuous with the thyroid tissue without any intervening connective tissue.

HERRING GULL (*Larus argentatus*). (Age 3 years 8 months.)

Thyroid.—Left lay between the carotid artery and jugular vein, its axis being directed antero-posteriorly. At the side of the posterior pole, and in contact with it, was a parathyroid.

Right was on the ventral surface of the carotid artery, its axis running backwards and inwards. Pressed against its lateral border was a parathyroid. Another similar-looking body at its anterior pole proved to be a lymphatic gland.

Microscopical Appearances. –The thyroid was peculiar in that all the vesicles were lined by regular cubical epithelium of a greater height than is often found in birds. Interstitial cells were very rare. The general appearance suggested a mammalian rather than an avine organ.

There was no noteworthy feature about the parathyroids.

Pygopodiformes.

The families of Podicepidæ and Uriadæ each provided one member. In the Guillemot there was one parathyroid to each thyroid lobe, but in the Little Grebe only an imperfect examination was possible.

Little Grebe (*Tachybaptes fluviatilis*).

Thyroid.—Right lobe had been cut away with the skin.

Left was at the usual position, with a small pale gland at its posterior lobe.

Microscopical Appearances.—Specimens mislaid.

Guillemot (*Uria troile*).

Thyroid and parathyroid were found in the usual position.

Microscopical Appearances.—The thyroid was composed of a closely set mass of vesicles, each lined by flattened epithelial cells (occasionally flat cubical), and filled with colloid. As a rule, the vesicles abutted directly on their neighbours, but here and there intervened clusters of interstitial cells.

Parathyroids were normal.

Lamellirostes.

The solitary example was one of the Cygnidæ—a Black Swan—in which there was one parathyroid to each lobe of the thyroid.

Black Swan (*Cygnus atratus*). (Age 3 weeks.)

Thyroid.—Both lobes were in the usual position. To the ventro-lateral part of each was attached a white parathyroid.

Microscopical Appearances.—The cells of the thyroid vesicles were cubical. Very few parathyroid cells.

Parathyroids normal.

Crypturi.

The one specimen obtained of this order was the Tataupa tinamou—family Tinamidæ (Pl. II. fig. iv.). An isolated parathyroid was found on the right, none on the left. The thyroid itself was parathyroidal throughout.

Tataupa tinamou (*Crypturus tataupa*).

Thyroid.—Right was apposed to the jugular vein on its lateral surface just anterior to the level where it was crossed by the carotid artery. Each extremity

of the gland showed paler than the middle portion, and clinging to the posterior pole was a small parathyroid.

Left lay on the jugular vein at the same level as the right. A pale area occupied a part of its ventral surface. No parathyroid was found.

Microscopical Appearances.—The thyroid was divided by connective tissue into compartments, each of which was filled by a solid cluster of polyhedral cells. There was no lumen and no colloid. At the surface of the gland these clusters showed a distinct tendency to acinar grouping, one larger than the rest being distinctly vesicular and containing a mass of colloid within an epithelial layer of the short cubical cells.

Parathyroid normal.

Struthiones.

The natural order of Struthiones afforded one example, the Ostrich (Pl. II. figs. xi. and xii.).

In this bird there were on each side two parathyroids separated from each other by connective tissue and lying on the ventral surface of the thyroid gland. To the naked eye the parathyroids on the left appeared to constitute a single bilobed gland, but on section a complete septum divided the structure into two.

Ostrich (*Struthio camelus*).

Thyroid.—The right lobe lay at the root of the neck in contact with the carotid artery on its median aspect and was brown in colour. It was the size of a small plum, and measured 2·5 cm. by 2·0 cm. The shape was suggestive of a broad bean, being much flattened dorso-ventrally and thus presenting two surfaces, a dorsal and a ventral—the latter being concave—and two convex borders, a median and a lateral. The middle of the lateral margin was drawn into a blunt process which rested against the carotid artery. On the ventral surface were two separate parathyroid glands, each the size of a large pea, and separated from the thyroid and from each other by connective tissue.

The left lobe lay in a position corresponding to that of the right, and was of identical colour. It was considerably the smaller of the two glands, not exceeding a grape in size (2·0 cm. × 1·6 cm.), and was compressed dorso-ventrally like its fellow, though to a less degree, and presented two convex surfaces, a dorsal and a ventral. The convexity of the latter surface was interrupted at its antero-lateral quadrant by a depression in which rested a bilobed parathyroid of the same colour and consistency as the thyroid itself. This latter on its outer border was distinctly impressed by the carotid artery, from which it could be easily separated. On the outer side of the artery was a large yellowish gland with a nodular surface which proved to be a lymphatic gland. No corresponding body had been found on the right.

Each gland was supplied by a special artery arising from the branch of the carotid artery coursing past its posterior pole, and was drained by two veins emerging from the same pole close to the site of entry of the artery, which soon united to form a direct tributary of the jugular vein.

Microscopical Appearances.—The thyroid consisted of closely fitted vesicles the majority of which were in outline polygonal rather than round or oval—the result

of mutual pressure. The connective tissue binding them together was of the finest. The lining epithelium was almost invariably flattened, though in a few of the very small follicles it approached the cubical type. The colloid was everywhere homogeneous.

In many places where the boundary walls of three or more vesicles met, the connective tissue was split to form lymphatic spaces in which were found drops of colloid. The blood capillaries ran in the trabeculæ.

The parathyroids were two in number on each side. On the right they were separate to the naked eye, but on the left microscopic examination was required to prove that there was a complete septum dividing the bilobed gland. Sections showed the parathyroids to be cut up into innumerable compartments by connective tissue, each containing a mass of parathyroid cells. In no case was there any attempt to form vesicles, nor was colloid found in either gland. The capillaries, which were numerous, ran in the septa.

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EXPLANATION OF PLATE II.

PLATE II.—Showing variations in position of avine thyroid and parathyroid glands.

References—

Acc. T.	accessory thyroid.	*Liv.*	liver.
C.	carotid artery.	*Œs.*	œsophagus.
Ht.	heart.	*P.*	parathyroid gland.
J.	jugular vein.	*T.*	thyroid gland.
L.	lymphoid tissue.	*Tr.*	trachea.

Fig. i. Maguari stork (*Dissura maguari*).
Fig. ii. Herring gull (*Larus argentatus*).
Fig. iii. White ibis (*Eudocimus albus*).
Fig. iv. Tataupa tinamou (*Crypturus tataupa*).
Fig. v. West African love-bird (*Agapornis pullaria*).
Fig. vi. Long-eared owl (*Asio otus*).
Fig. vii. Scaly ground dove (*Scardafella squamosa*).
Fig. viii. Kestrel (*Tinnunculus alaudarius*).
Fig. ix. White ibis (hybrid of *E. albus* and *E. ruber*).
Fig. x. Crowned crane (*Balearica pavonina*).
Fig. xi. Ostrich (*Struthio camelus*), left thyroid and parathyroid glands (ventral and dorsal aspects).
Fig. xii. Ostrich (*S. camelus*), right thyroid and parathyroid glands (ventral and dorsal aspects).

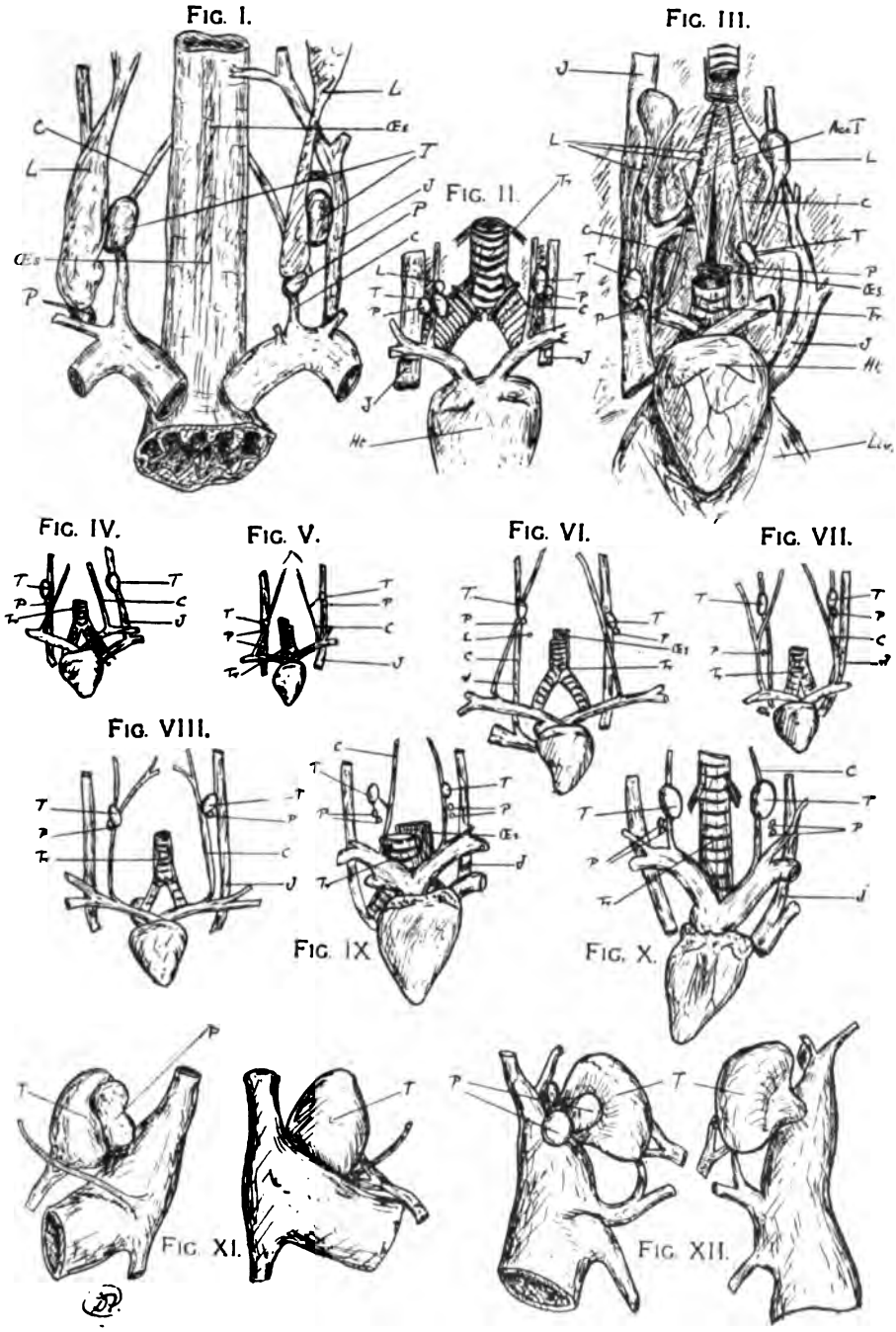

Fig. I.
Fig. II.
Fig. III.
Fig. IV.
Fig. V.
Fig. VI.
Fig. VII.
Fig. VIII.
Fig. IX.
Fig. X.
Fig. XI.
Fig. XII.

Plate II.

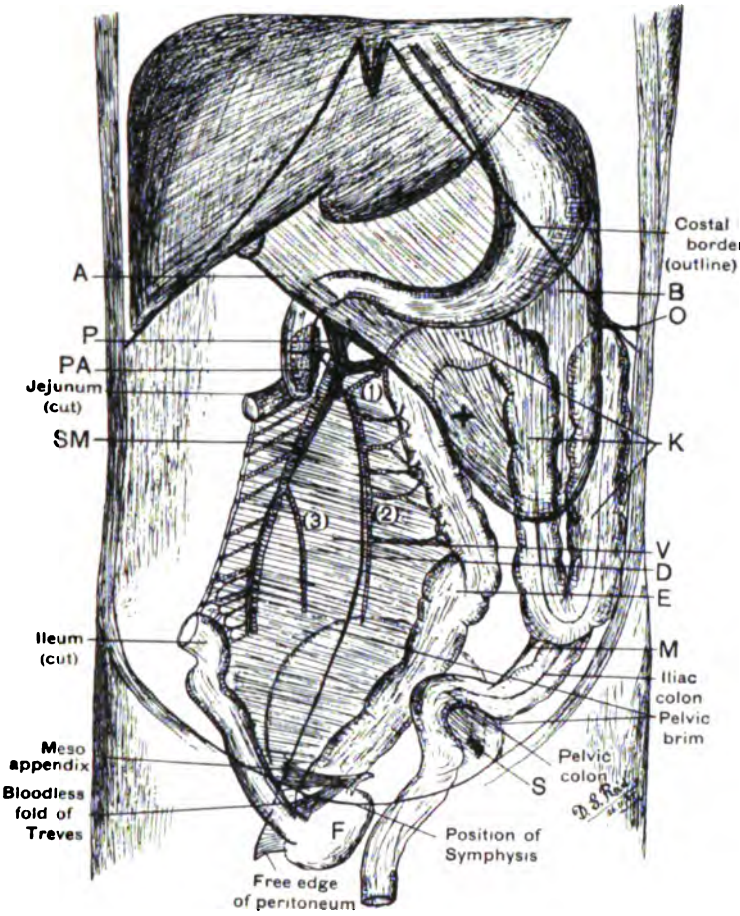
IMPERFECT TORSION OF THE INTESTINAL LOOP.

By DOUGLAS G. REID, M.B., Ch.B. Edin., *Demonstrator of Anatomy in the University of Cambridge, Trinity College.*

THE loop referred to in the title is the embryonic intestinal loop, which in the case under notice (see figure) was minus the transverse colon and plus the third portion (pars inferior) of the duodenum. The neck of the loop was formed by the second part (pars descendens) of the duodenum and the right end of the transverse colon. But the disposition of the gut was unusual in that the limb formed by the large intestine, and that formed by the small, lay the former on the left, the latter on the right of the superior mesenteric artery. Such, as regards the bowel, was the outstanding feature of this interesting condition. There was no indication of old peritonitis or other pathological condition to take away the value of the picture. The body was that of a man over sixty years of age who died of cerebral hæmorrhage, and presented no other outstanding anomalies than those of the intestinal canal whose details are here recorded. The stomach was more attenuated in shape than usual. There was a very well-developed hepatocolic ligament (see fig., A), and the foramen of Winslow was normal. The great omentum (see fig., B) presented its usual inseparable attachment to the middle portion of the colon and mesocolon, and was similarly fused with the upper portion of the ascending colon.

The rest of the duodenum requires a more detailed description. It was unusually mobile and lay altogether to the right of the mesial plane, was not related in front to the colon, to the root of the mesentery, or to the jejunum. The descending portion had the usual direction, and lay about 5 cms. from the right end of what, from its position, may be considered to represent the transverse colon, and with it formed the neck of the loop of bowel. The short third part of the duodenum lay entirely posterior to the second portion of the duodenum, from which it was separated by the head of the pancreas. Its direction was to the left and slightly upwards. Reaching the bifurcation of a very short common stem of the inferior pancreatico-duodenal artery and of the uppermost of the vasa intestini tenuis, the bowel at this level, close to the right side of the superior mesenteric artery, turned acutely to the right and downwards, becoming

jejunum. This for quite 4 cms. was also covered in front by the second portion of the duodenum (see figure). But wedged in between them, and separating them to a large extent from one another, was the lower part of the head of the pancreas.



The surfaces of the duodenum, jejunum, and pancreas, which were in apposition with each other, were bare as regards peritoneum. The posterior aspect of the third portion of the duodenum was free behind, the peritoneum leaving the upper border of this aspect to reach the posterior abdominal wall along an almost horizontal line which formed the upper duodenal portion of the line of soldering (see fig., D) to be described. Inasmuch as

the second part of the duodenum, head of the pancreas, and jejunum came into antero-posterior relation with one another the mesentery of the last named was common to all. All were thus equally mobile. Above the jejunum a lamina of peritoneum (part of the originally right lamina of the mesoduodenum), lying in the frontal plane, and about 2 cms. long, connected the second part of the duodenum to the posterior abdominal wall quite to the right of the superior mesenteric artery. Upon the front of this lamina was a rather well-developed muscle of Treitz embedded in connective tissue, representing part of the originally left lamina of the mesoduodenum. To become continuous with the muscular wall of the third portion of the duodenum this muscle passed downwards upon the right side of the superior mesenteric artery. The connective tissue and muscle just described were covered in front by the posterior (ordinarily anterior) surface of the head of the pancreas, just at its upper part. But, covering this surface of the head of the pancreas, and intervening, was a fascia which also represented the connective element of the original left lamina of the mesoduodenum. The third portion of the duodenum was sessile. Of the appendages of the duodenum the liver, at least, presented nothing unusual. Practically the whole of the head (see fig., PA) of the pancreas lay clasped between duodenum in front and duodenum and jejunum behind. It did not lie behind either of the superior mesenteric vessels; indeed, its left border, projecting somewhat beyond the descending portion of the duodenum, overlapped the artery in front. This border, however, owing to the peculiar disposition of the duodenum, corresponded to the right border of the usual adult head of the pancreas. In other words, there was absence of the little pancreas of Winslow (processus uncinatus pancreatus). Perhaps a mere rudimentary development in connection with the right (which corresponded to the usual left) border of the head of the pancreas represented it. Nevertheless, the condition of matters present only went to confirm the statements made to the effect that the development of the pancreatic uncus corresponds to the degree of leftward shift of the jejunal end of the duodenum.

It may be stated at once that the intestinal loop—excluding the already described third portion of the duodenum—possessed a dorsal lamina, which had acquired a narrow line of soldering, and a ventral (the loop, of course, was in the frontal plane) lamina of peritoneum. The small intestinal limb of the loop was without a Meckel's diverticulum. Tracing the dorsal lamina of the peritoneum (mesentery) in connection with the small intestine, it was found to pass to a line (see fig., D) of most definite soldering on the posterior abdominal wall and inner surface of the right wall of the pelvis. Starting above in continuity with the duodenal line of soldering it passed, with a gentle curve, downwards and to the left, then downwards and to the right.

After lying for some distance upon the front of the aorta and in the middle line, it went medial to the right common iliac artery into the pelvis. The ventral lamina (see fig., V), lying upon the subjacent superior mesenteric artery and its branches, was carried directly—by which is meant that it had no line of soldering whatsoever—to the ascending colon. Thus nothing really resembling the root of "the mesentery" of the usual adult existed. The cæcum (see fig., F) lay inverted and wholly intrapelvic; it presented its usual adult form. The lower part of the ascending colon was also intrapelvic. In obtaining this position it had tended to shove the cæcum up again into the abdomen, and had so inverted it. The ascending colon (see fig., E), save for its lower end, lay entirely to the left of the mesial plane. It coursed upwards and to the left, then upwards and to the right, going over into the transverse colon at the neck of the loop.

Peritoneal Relations.—Examining the intrapelvic part of the ascending colon, it was found that the fingers could be introduced behind it into a number of peritoneal fossæ, and in these could be pushed, without rupture of peritoneum, right up to the intrapelvic line of soldering, where their progress was arrested. Therefore the dorsal lamina of the peritoneum of this portion of the intestinal loop, save for a narrow line of soldering to the pelvic wall, and some imperfect blending with the parietal pelvic peritoneum resulting in the formation of a row of five well-marked fossæ, existed in its primitive, free, unfused condition. The abdominal portion of the ascending colon had acquired a flimsy, bloodless connexion with the parietal peritoneum, and its upper part was related, as already described, to the great omentum, and thus were concealed the true relations of the parts. An opening having been made through the two layers of the great omentum (at + in figure), the fingers could be passed behind the ascending colon into a peritoneal cavity bounded in front by the two lamina of peritoneum connected with the ascending colon, between which blood-vessels were lying, furnishing thus a clue to the situation; bounded behind by the parietal peritoneum; and to the right by the line of soldering (see D in fig.). Below, it reached downwards as far as the bifurcation of the aorta; and fingers introduced into the two uppermost peritoneal fossæ could be passed upwards over the pelvic brim to this level, so as to meet, only separated by the walls of the fossæ, the fingers in the compartment. In all situations the fingers could be pushed, without tearing of peritoneum, right up to the line of soldering, where their advance was barred. Thus the intra-abdominal dorsal lamina of the peritoneum of the loop also existed in its primitive, free condition, except for the narrow line of soldering. Above, at the level of the origin of the artery of the transverse colon (see fig., (1)), the dorsal lamina passed into the lower lamina of the mesentery of the colon with the upper lamina,

of which the ventral lamina of the peritoneum of the loop, of course, became continuous.

The part corresponding to the normal transverse colon (see fig., K) was not in the common sessile condition. Its extremities lay in practically the same horizontal plane. One, as already mentioned, formed part of the neck of the intestinal loop. The splenic flexure was in its usual adult position, inferior to the phreno-colic ligament (see fig., O). Transverse only for a short extent of length, this part of the colon for the rest of its course took the form of a loop whose limbs were closely apposed and, indeed, bound together by peritoneum, and fixed by a common mesentery to the posterior abdominal wall. The lower extremity of this interesting colic loop descended an inch or so below the inter-tubercular plane. The root of its mesentery skirted, from below upwards—its lower end (see fig., M), in truth, passing on to the side of the pelvic colon—the right aspect of the iliac, and the similar aspect of the descending colon.

All the bowel caudalwards from the splenic flexure presented no noteworthy feature. The descending colon lay dorsal to the ascending limb of the colic loop; neither it nor the iliac colon possessed a mesentery The intersigmoid fossa (see fig., S) was well developed.

Vascular Relations.—The superior mesenteric artery (see fig., SM) as it entered the neck of the intestinal loop lay to the left of the duodenum and head of the pancreas. The duodenum was, therefore, not within the limbs of the usual superior mesenteric and aortic Λ. Nor was the artery within a pancreatic embrace. The vessel, almost immediately crossing the line of soldering so as to lie thereafter entirely to its right, took a course curved with convexity directed to the right. The superior mesenteric vein lay from below upwards first to the right, then behind, and to the left of the artery, overlapping it somewhat in front, and was joined, considerably below the neck of the pancreas, by the splenic vein. The portal vein (P) so formed crossed in front of the artery. If we imagine the intestinal torsion to be completed, the usual relation of the vein to the artery would be obtained. The arteries of the jejunum and ileum (and a large accessory hepatic artery) had their origin from the right convex aspect of the superior mesenteric. The very short common stem of the inferior pancreatico-duodenal artery, and of the uppermost artery to the jejunum, arose from its right and posterior aspect. The ileo-colic (see fig., (3)), and a common stem of the arteries of the transverse and ascending colons, took origin from its left concave aspect. The latter coursed to the left and upwards, and at the line of soldering divided into its two parts. The artery of the ascending colon (see fig., (2)) followed closely the line of soldering, but diverged to its left below; it was placed throughout

between peritoneal laminæ. An especially noted point, then, was that the peritoneum of the intestinal loop was free from adhesion to the right and left of the artery of the ascending colon in part of its course. The branches of the artery of the ascending colon arising from its left aspect coursed to the left—not behind the parietal peritoneum, but between the laminæ of peritoneum already described. The artery of the transverse colon (middle colic (see fig., (1)) entered at once between the two laminæ of the mesentery of the transverse portion of the transverse colon. It gave here a branch to this part, and a second which, leaving the mesentery, coursed behind the perietal peritoneum to enter the mesentery of the colic loop. The artery of the descending colon (left colic) also entered this mesentery to supply the colic loop before supplying, by means of one of its two terminal branches, the adjacent descending colon.

THE DERIVATION OF THE HUMAN HYPOTHENAR MUSCLES.

By J. ERNEST FRAZER, F.R.C.S., *Anatomical Department, King's College, London.*

WHEN considering the derivation of the muscles of the hypothenar group, it is a matter of interest and importance to know what changes are undergone by these muscles in their ontogenetic development and to see if these throw any light on the questions concerned; the more important of these changes take place during the first three months of intra-uterine life, and I propose to consider them shortly and to discuss the morphological value of the muscles from this and from other points of view.

The drawings are from linear reconstructions, and have been made of about the same size for convenience, but the metacarpal length and approximate age are given at the same time.

1. *Opponens minimi digiti.*—This muscle undergoes more radical change in position than either of the others: it cannot be demonstrated in the sixth week, but is probably represented by part of the mass of deeply staining cells found at that stage on the palmar surface of the metacarpal rudiment.

Later, in the seventh to eighth week, it is easily distinguished, and this stage is represented in fig. 1. The next two figures (figs. 2 and 3) show the condition at about the end of the second and early part of the third month respectively, and the changes that take place may be considered as affecting (*a*) its origin, (*b*) its insertion.

(*a*) The origin does not at first extend further than the metacarpal. Definite muscle cells can first be observed over the base of the metacarpal, and this part grows more in thickness at first than the rest of the muscle, which is closely applied to the shaft.

By the end of the second month the origin has extended along the cells that are laying down the carpo-metacarpal ligaments, and has reached the unciform process, and, in doing this, some of its fibres have passed *behind* the deep nerve, while the majority have passed over this nerve and artery.

Later, the origin has very much increased, extending on to the flexor sheath below the unciform process.

(*b*) The insertion would seem at first to have extended to the inner side of the phalanx, as is seen in fig. 2. The earlier example does not show this

extension, but I have no doubt that it was present, although I could not definitely trace it through the mass of cells (not shown in the figure) that lay round the neighbourhood of the joint. In the second specimen, where the tissues were more defined, the continuation of the muscle could be traced to the phalanx, but later than this the phalangeal connection is lost, and the structure could not be traced further than the front of the lateral ligament: it can be followed to this point up to the fifth month.

The thick interrupted lines in figs. 2 and 3 indicate the apparent longitudinal extent of the metacarpal insertion in these cases: the increase both in length and breadth of area was very marked in the latter one.



Fig. 1.

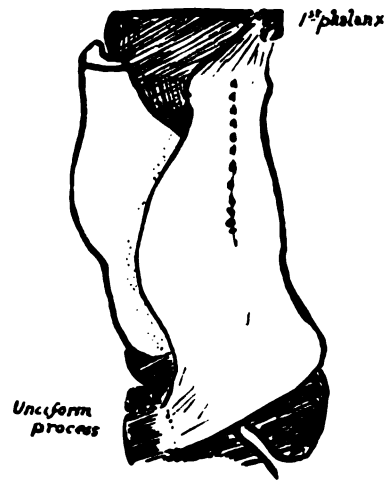


Fig. 2.

The opponens, when present in the human foot, has been traced by Ruge as derived in ontogeny from the flexor brevis of the little toe. Cunningham states that the group of opposing muscles may, when present, be regarded as derived from one or two sources—most commonly it is a development from the flexor brevis, but it may proceed, as in many of the Carnivora, from the plantar layer, and thus be associated with the adductors. (Perhaps to this list should be added the abductor as occasionally giving fibres to the metacarpal: it certainly does in some animals and occasionally in man, and it seems to vary in this respect in the lower animals, as in the Virginian opossum, in which Young describes the marginal muscle (abductor) as having a metacarpal insertion, which Brooks did not find.)

St John Brooks held that the muscle in the human hand is a composite

one, that part deep to the deep ulnar nerve being derived from the ulnar head of the intermediate flexor, while the superficial or functional part comes with the flexor brevis from the adductor or contrahens quinti digiti, which has spread inwards along the overlying flexor sheath and has thus reached the unciform, maintaining its proper nerve relation.

These views seem to be generally accepted by British anatomists, and are founded on dissections of various mammalian hands: the records of these dissections by Brooks with those of Cunningham, Young, and others, form a mass of available material for the comparative study of the subject. I have taken advantage of these careful records in addition to a number of



FIG. 3.



FIG. 4.

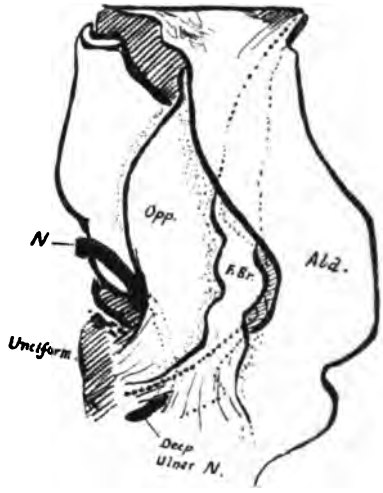


FIG. 5.

observations I have made myself on monkeys and some of the commoner animals possessing four or five digits. The dissections of animal hands did not seem to me to be of overwhelming value when dealing with the human subject, but I confess that I read into them a meaning quite different to that reached by Brooks, and this meaning has been to a great extent supported by observations on the developing human hand.

M'Murrich, writing on the phylogeny of the palmar musculature, has extended his investigations to the hands of reptiles and amphibia: it will be more convenient to consider this aspect of the question later.

Study of the early conditions of the opponens in the human embryo points very strongly to the homology of the complete muscle with the ulnar head of the intermediate flexor. This derivation is admitted for the deeper part of the muscle, but the remaining "functional" part is differently

considered, owing to its superficial relation to the deep ulnar nerve: yet the head can and does spread over the nerve in various animals, as in the opossum described by Young, and the fact that it does do so in man disposes at once of any question of impossibility. As might be expected, the deepest fibres of the primitive muscle are those that reached the base of the process and remain deep to the nerve, running a very short course to the proximal part of the metacarpal.

The main mass of the muscle spreads over the nerve, and, having reached the process, does not spread any further in this direction, so that any further extension must be upwards or downwards and must be undertaken by the *deeper* fibres of this main mass. The presence of the abductor and flexor brevis may account for the extension being downwards, but it seems to me that that extension is more probably due to the greatly increased power of action so obtained, which power would be further added to by the simultaneous proximal extension of the metacarpal insertion.

The great increase of origin downwards of these deep fibres is well shown in fig. 3 with their relation to the earlier unciform fibres.

The absolute continuity from the beginning of the deep and superficial parts of the opponens is certain, and there is no other muscle to be found that shows any tendency to become involved in this continuous mass.

This brings us to a consideration of the view that the contrahens quinti digiti, by extending its origin ulnarwards along the flexor sheath, gives rise to the functional part of the opponens.

This conception of the derivation of the muscle was founded by St John Brooks on observations made on a variety of mammalian hands: the facts observed seem to me to admit of other explanations equally well, but in addition a few reasons may be given against this view.

(*a*) The opponens and contrahens have different places of insertion, *i.e.* the former muscle goes to the ulnar side, while the latter reaches the radial side (of the phalanx) *behind* the radial head of the intermediate flexor, which must therefore separate the two muscles. It follows from this that when the contrahens extends its insertion it will probably do so on the radial side of the metacarpal *behind* the radial flexor, and, as a matter of fact, this is what does occur in all animals that possess such an opponens, so far at least as I am aware.

(*b*) There is no evidence of extension of adductor insertion ulnarwards in man or other animal.

(*c*) There is no example of any apparent continuity of opponens and contrahens anywhere but at their origin, which is the most variable part of muscles so far as extension to surrounding

structures is concerned: two muscles spreading their origin in the same plane and meeting would produce the effect of "fusion" of their origins.

(*d*) The opponens can be present and well developed, while the contrahens quinti is present also, well developed, and remote, with no connection between the muscles. It might be said that this last objection is of no weight in considering the human hand, but in man the contrahens quinti develops and is plainly visible in the latter part of fœtal life. I have fœtal hands in my possession prepared to show the muscle, and it is evident that there is no connection with the opponens. Moreover, and this seems to me an important point, the opponens, as I have shown, begins to be recognisable in the latter half of the second month, whereas the contrahens is not present for some months afterwards, and in the interval I have not been able to find the faintest trace of any structure connecting the opponens with the adductor region.

To sum up, then: for the reasons I have briefly given, and especially considering the ontogeny of the human muscle, I think there cannot be much doubt that, in man, the opponens minimi digiti, in all its parts, is the homologue of the ulnar head of the intermediate flexor in other animals and is directly derived from it.

2. *Abductor and Flexor brevis.*—Various views have been held about these muscles. On the trilaminar-type theory it was considered that the abductor was a marginal muscle of the dorsal layer which had extended its origin proximally, while the short flexor belonged to the intermediate layer. Previously, Meckel had stated that the abductor and flexor brevis form only one muscle, representing the last dorsal interosseous. St John Brooks classed the short flexor with the functional part of the opponens as owning an "adductor" origin, and Bland-Sutton refers the abductor to the inner part of the palmaris longus. M'Murrich considers that all the hypothenar muscles are derived from the ulnar part of his "flexor brevis superficialis."

Brooks' view seems to be that accepted by English text-books, and was advanced to explain the same nerve relation as in the case of the opponens, was founded on the same grounds, and is open to the same objections as in that case.

I brought before the Anatomical Society, last year, reasons for supposing that the short flexor should be considered merely as an extension of the marginal abductor, and I would like now to add to these reasons, which were mainly comparative and late fœtal, the conditions of the muscles in the earlier embryonic period.

The first indication of the abductor occurs in the sixth and seventh week, while the intermediate flexors are still undifferentiated: the commencement of formation of the muscle cells is evident, extending from the situation of the pisiform downwards for some little distance over the metacarpal. Behind this, and below it, the developing muscle is lost in the mass of undifferentiated cells which continues down to the finger bud.

This early formation of the abductor may depend on the growth of the ulnar nerve, which reaches the hand about this time, and might be expected to give filaments here before those to the deeper muscles. At a later stage (fig. 4), the muscle is seen internal to the nerve, but, opposite the upper part of the small unciform process, some of its fibres are lying over the nerve. I followed these fibres carefully upwards, *i.e.* in the direction of their origin, and found that they were lost in the cells immediately covering the nerve, while traced in the other direction they joined the mass of the muscle. I had expected to find them running up to a definite layer of cells that stretched from the flexor sheath across the process, over the nerve and muscle internal to it, but they had no connection with this, and, on reflection, it could only be expected that a muscle extending like this should spread by its deep aspect.

Still later (fig. 5), the spreading outer and deep fibres have reached the process, and have formed the short flexor.

The abductor is usually regarded as derived from the marginal muscle mass completing the series of inter-metacarpals, or Cunningham's "dorsal layer," and this seems a very good basis on which to explain its presence. It is rather out of keeping with this view to find the muscle first showing itself in connection with the pisiform, and this connection at first brought to my mind the question of a post-minimus represented by that bone: if such a structure were admitted, then the position of the muscle is explained at once, otherwise it is difficult to offer an explanation, save the more or less unsatisfactory one, in the light of the changes in the opponens, of "abbreviation of development."

I have looked for evidences of other attachment, and find that in no stage is there any apparent attachment to the cuneiform or unciform, but there seems to be at first an attachment to the cells of the fibrous tissue about the base of the metacarpal and down the metacarpal below this and behind the opponens. It is difficult to be certain that one is dealing with definite attachment in these very young specimens, but if the observation is correct it certainly cannot be taken as favouring the view of a marginal muscle extended from the metacarpal as much as that of a post-minimus with its inter-metacarpal muscle also attached to the next metacarpal.

Leaving out of account this question of origin of the abductor at lower

points as well as from the pisiform, its history might be shortly given as developing in a mass connecting the pisiform with the ulnar side of the digit, and later, before the end of the second month, spreading over the deep nerve and vessels to reach the unciform process, this spreading being done by deeper fibres, as in the later spreading of the opponens.

Thus the flexor brevis is formed from the deeper anterior fibres of the abductor, and is covered from the first by the same fascial sheet as the latter: this sheet is seen in the last figure, and is apparently derived from the layer of cells previously mentioned as covering the spreading abductor on the surface. The short flexor seems to extend its origin over a large part of the breadth of the annular ligament in the early part of the later months, but ultimately to retrogress and reach its permanent condition.

I have been able to follow the nerves of supply to these hypothenar muscles in some cases: that to the abductor comes off from the division of the main nerve (or from the commencement of the deep) in early stages, and supplies the whole of the mass, so that the filament to the short flexor arises in common with that to the abductor, and is drawn with the muscle across the deep nerve. The nerve to the opponens arises much lower, as the deep nerve turns outwards round the unciform and supplies the whole mass. I have only once found the nerve supplying the deep part of the opponens in an adult, and in this case it arose as a branch of the nerve to the superficial part.

In the last figure, the insertion of the abductor is shown as extending across the front of the head of the metacarpal: in the specimen from which the reconstruction was made this appearance was produced by the presence of a few strands of muscle cells that ran up, as shown in the figure, towards the front and radial side of the articulation to reach the inter-metacarpal ligament, or side of the flexor sheath. I have not been able to find such a strand in other specimens.

The abductor and short flexor on the one hand and the opponens on the other are distinct from each other in all stages, particularly throughout the metacarpal area, where they are separated at first by layers of cells that afterwards form a strong fascia continuous in the early stages with that on the extensor surface. But near their origins the separation is not always so distinct, and from a study of some sections of one specimen it has seemed to me that there is a possibility of fusion of some of the deeper fibres of the short flexor with those of the opponens lying in contact with it. I could not reproduce the appearance in a reconstruction, so must content myself with the suggestion that the superficial fibres of the opponens *may* have some of those properly belonging to the short flexor incorporated with them, and this suggestion offers an explanation of a form of nerve supply

that I have come across once, though it may be more frequent than I imagine—in a hand (adult) apparently normal, the nerve to the short flexor was continued through it to the surface of the opponens, and this muscle had in addition its ordinary supply. The suggestion would also explain the occasional fusion of the two muscles, and it is possible that some of the deeper fibres of the abductor mass might, as in some animals, attain a metacarpal insertion, but of this I have no evidence.

It does not seem necessary or justifiable to call in the palmaris longus as the origin of the abductor, as suggested by Bland-Sutton, unless as an explanation of some of the accessory heads of the muscle. The palm is largely covered by muscle cells derived from the palmaris group in the early stages, and I have followed this sheet of fibres on the ulnar side as far down as the level of the metacarpal head, lying on the marginal mass but distinct and separated from it by several layers of cells. Later, this layer thins out considerably, breaking up and tending to disappear, and lying more immediately in contact with the abductor and short flexor: the accessory heads from the fascia or palmaris longus would be accounted for by the persistence of one of these strands.

M'Murrich has more recently brought forward the view that the "intrinsic" muscles of the mammalian hand are, properly considered, composed of five layers, derived from seven layers in the Lacertilia and four in the Urodela. It would be impossible to discuss here the fundamental matters of these important papers, however shortly, and I need only consider some details bearing on the human hand.

The three hypothenar muscles are classed together by him as belonging to one mass, derived from the ulnar marginal part of the superficial stratum of the "Flexor brevis superficialis," whose central portion degenerates to form the tendons of F. sublimis. He figures and describes the *ulnar* head of the fifth intermediate flexor as going to the *radial* side of the digit; while the *radial* head, incorporated with the dorsal or inter-metacarpal layer, has gained an insertion on the *ulnar* side of the next digit.

I find it quite impossible to agree with this statement concerning the intermediate short flexor quinti, for I consider that the two normal heads are well represented in the embryo, as in the examples in the first three figures in this paper: if this presence of the normal heads is admitted—and I can see no reason why it should not be admitted—then the opponens is at once separated from the other hypothenar muscles and derived from the layer of intermediate flexors.

If the grounds on which the hypothenar mass is brought into line with the superficial stratum are shown to be of no account in the case of the opponens, it might perhaps be said that their value is impaired when deal-

ing with the other two muscles. This may be so, but I do not think a definite opinion could be formed without such a fundamental consideration of the theory as would be outside the scope of the present paper: I have searched for evidence bearing on the matter in early embryonic hands, but so far without success; and as little importance can be attached to such negative results, I will content myself with the expression of my own view, that these muscles are developed as a marginal mass, corresponding with similar marginal masses in other mammalian hands, leaving open the question of mammalian derivation.

Summary.

1. The opponens minimi digiti is derived from the ulnar head of the intermediate flexor quinti, and ontogenetically shows its extension from this. The "functional" part, as well as the deep part, is derived in this manner.

2. The flexor brevis is derived in ontogeny from the abductor mass, secondarily spreading over the deep vessels and nerve.

3. The abductor mass is a marginal mass in mammalia, that may be in series with the "dorsal" or inter-metacarpal muscles, but its further derivation is doubtful.

4. Perhaps in some cases the flexor brevis may give from its deep surface some fibres to the underlying opponens: additional heads to the other muscles are probably derived from a distinct and superficial palmaris layer.

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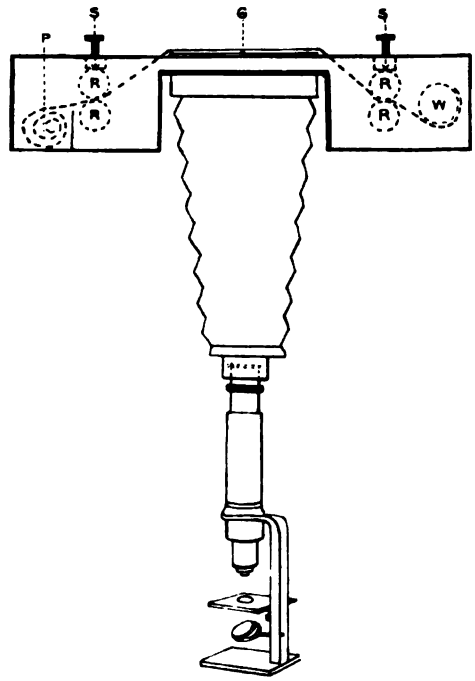
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THE CAMERAGRAPH: A Drawing Apparatus suggested by EVELYN JOHN EVATT, *Lecturer in Applied Anatomy, University College of South Wales and Monmouthshire, Cardiff.*

THE cameragraph is a contrivance by means of which tracing paper may be stretched over a plate of clear glass at the back of a camera and retained



Cameragraph.

G, glass plate; P, roll of paper; R, rubber rollers; S, thumb-screws; W, winder.

in this position. Reference to the accompanying diagram will show how this is done.

The tracing paper at the back of the camera, supported on the clear glass, takes the place of the ground-glass focussing screen of the camera; any image which can be projected on to the focussing screen may, under the

same conditions, be cast on to the tracing paper which occupies its place, and traced straight on to the paper. When the illumination is good, as from an electric or lime light, white paper of the thickness of ordinary glazed notepaper may be used instead of the screen, and images of objects magnified with a $\frac{1}{6}$-inch objective and an eyepiece may be obtained on it. Further, by the use of the cameragraph, tracings of the surface markings of opaque objects, and drawings of objects reduced in size, can be made.

A roller or winder enables one to draw away the paper when a tracing has been made, and a fresh piece of paper is brought into position to receive a second tracing, and so on. In this manner a series of tracings of consecutive sections, such as one uses for purposes of reconstruction, may be obtained. Lastly, whilst drawing, no shadow is cast by the pencil or hand on to the paper, since the operator does not come in between the object and its image.

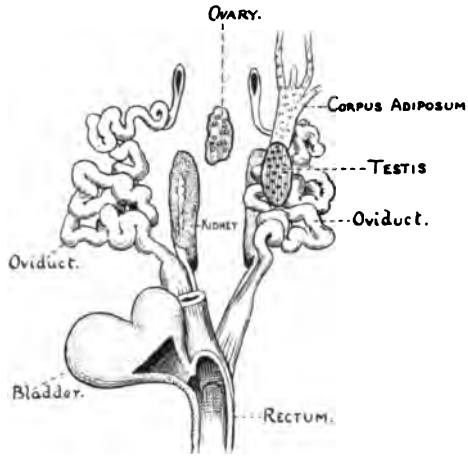
Mr C. Baker, of 244 High Holborn, London, has kindly undertaken to manufacture this instrument.

TWO CASES OF HERMAPHRODITISM.

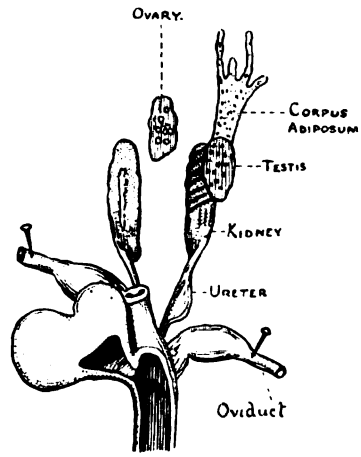
By Dr STRICKLAND GOODALL,
Lecturer on Biology and Physiology, Middlesex Hospital, London.

CASES of hermaphroditism occurring in normally unisexual animals are so rare as to always be interesting and worthy of record. Hermaphroditism does of course normally occur in certain fishes. In Myxine the posterior part of the gonad gives rise to spermatozoa, while subsequently the anterior part forms ova, an arrangement by means of which self-fertilisation is prevented. Serranus again is bisexual, while cases of hermaphroditism have also been described as occasionally occurring in other fishes (normally unisexual), such as *Gadus morrhua*, *Scomber scomber*, *Clupea*, and *Harengus*. In amphibians the Anura are occasionally hermaphrodites, but among urodeles *Triton tænialis* alone exhibits this condition. In some species of toads a body attached to the anterior end of the testis is reputed to be capable of giving rise to ova and spermatozoa, while in the males of Rana temporaria ova are very occasionally said to occur embedded in the substance of the testis (an ovo testis), or one testis may even be replaced by a rudimentary ovary. In such cases the Mullerian duct is said to be as well developed as in the female. This condition of hermaphroditism in the frog must be extremely rare, as the cases here recorded and described are the only ones which have occurred during fourteen years' biological and physiological work, in which practically all the animals used for either dissecting or experimental purposes have been systematically examined for developmentally abnormal or pathological conditions. The first case recorded was met with in the Biological Laboratory of the City of London College in 1894. The animal, *Rana temporaria*, was well developed, but prior to dissecting did not exhibit any very definite sex characteristics; but on the whole the shape of the body and the absence of any very definite pigmented pads at the bases of the thumbs suggested a female rather than a male animal. On dissection there was a well-developed oviduct on each side; these bore the usual normal relationship to the cœlom and cloaca respectively, and appeared to be in every way normal. On the left (side), surrounded on all sides by the convoluted oviduct, was a well-formed testis; this was connected to the inner border of the left kidney by about seven vasa efferentia. There was also on this (the left) side a well-marked corpus adiposum, which appeared at the upper border of the kidney

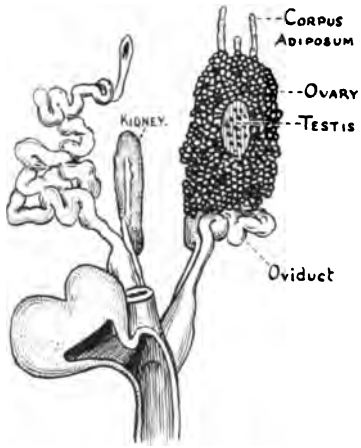
and was apparently attached (as is normal in the male) to the anterior margin of the testis. On the left side also, in addition to the oviduct,



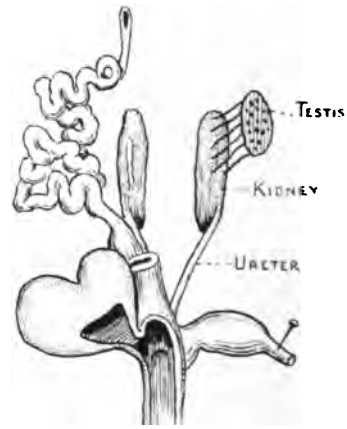
Case I.—C.L.C., 1894.



Case I.—Oviducts removed.



Case II.—Middlesex Hospital, 1898.



Case II.—Ovary and Oviduct removed.

there was a well-developed genito-urinary duct, running from the outer and dorsal aspect of the kidney to the cloaca. On the postero-lateral aspect of this duct in quite the normal male position was a well-marked seminal vesicle. On the right side there was no testis, no urogenital duct, and no

seminal vesicle. There was, however, a well-marked oviduct, as mentioned above, and near the middle line, and presumably belonging to this side, was a small shrunken remnant of an ovary, which had apparently discharged most of its ova.

The relationship between the systems on the two sides can be easily seen from the following table: —

Right side.	Left side.
(*a*) Oviduct present and well developed.	(*a*) Oviduct present and well developed.
(*b*) Ovary present.	(*b*) Ovary absent.
(*c*) Testis absent.	(*c*) Testis present.
(*d*) Ureter present.	(*d*) Urogenital duct present.
(*e*) Seminal vesicle absent.	(*e*) Seminal vesicle present.
(*f*) Corpus adiposum.	(*f*) Corpus adiposum attached to testis.

The second case turned up in the physiological department of the Middlesex Hospital in 1898. This frog prior to dissection had the large oval body so characteristic of the female, but had two small debatable pads at the bases of the thumbs. On dissection it was found that there was a perfect ovary and oviduct on each side; but embedded in the substance of the left ovary was found a fairly well-developed testis, which on further dissection was found to be attached to the left kidney by what appeared to be vasa efferentia, while extending backwards from the outer border of the kidney in the position of the genito-urinary duct in the male or the ureter in the female to the cloaca was a duct, either a true urogenital duct (ureter and vas deferens), or a ureter alone.

This duct presented no enlargement on it analogous to the seminal vesicle of the male. A small corpus adiposum was present on each side and was attached to the ovary in each case. The cloaca presented on the right side the openings of the oviduct and the ureter, on the left the openings of the oviduct and genito-urinary duct.

The main differences on the two sides may be summarised as follows :—

Right side.	Left side.
(*a*) Ovary present.	(*a*) Ovary present.
(*b*) Oviduct present.	(*b*) Oviduct present.
(*c*) Ureter present.	(*c*) Testis.
(*d*) Corpus adiposum present and attached to ovary.	(*d*) Urogenital duct present.
	(*e*) Vasa efferentia present.
	(*f*) Corpus adiposum present and attached to ovary.
	(*g*) No seminal vesicle.

In comparing these two cases it is interesting to note: (*a*) that in both cases the external features suggested a female; (*b*) in both cases the urino-genital system on the right side was practically that of a normal female: while (*c*) in both cases the male organ, presumably the abnormal developmental structure, was on the left side. If we compare the corresponding sides in the two animals, we find that on the right side the genito-urinary systems are practically identical, both presenting the characteristics of a well-developed normal female, the only difference being apparent absence of a definite corpus adiposum in case 1. This comparison is made obvious by the following table:—

Right side. No. 1.	Right side. No. 2.
Ovary.	Ovary.
Oviduct.	Oviduct.
Ureter.	Ureter.
? Corpus adiposum absent.	Corpus adiposum present and normal.

Turning now to a comparison of the left sides, we note that they resemble one another in the presence of a definite testis with definite vasa efferentia, which latter in case 1, however, pass to the outer border of the kidney instead of to the inner, as is usual, and the persistence of a well-marked oviduct. In case 2, although the testis was structurally a testis, it is doubtful if it was functionally very active, a view supported by the absence of a definite seminal vesicle and the attachment of the corpus adiposum to the ovary.

In case 1 the left-side genito-urinary system was almost certainly that of a male, functionally the whole apparatus being apparently perfect in every respect; and this case appears to be a really definite case of hermaphroditism, male and female systems occurring perfect in the same animal.

In both cases the right sides appear to have developed perfectly normally along the usual female plane, while in the case of the left sides the Mullerian duct had in both cases persisted; but in case 1 the genital gland had for some unknown reason become converted into a testis instead of an ovary, while in case 2 the genital gland became differentiated into two parts, one of which became converted into a testis, the other giving rise to an ovary, a state of affairs which occurs commonly in some species of toads.

The comparison between these two systems can be seen at a glance from the following summary:—

Left side. No. 1.	Left side. No. 2.
Oviduct.	Oviduct.
Testis.	Ovary and testis.
Urogenital duct.	Urogenital duct.
Vasa efferentia.	Vasa efferentia.
Seminal vesicle.	No seminal vesicle.
Corpus adiposum attached to testis.	Corpus adiposum attached to ovary.

The above seemed to me to be well worthy of record, as such cases must be extremely rare. The above two cases represent several thousands of dissections during fourteen years' active systematic biological and physiological work.

Since writing up the above cases I have had the opportunity of looking up the literature of the subject (a list of which is appended). This research into the literature has further convinced me the cases are worthy of record, as very few of the recorded cases are at all fully described.

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A CASE OF FUSION OF THE SEMILUNAR AND CUNEIFORM BONES (OS LUNATO-TRIQUETRUM) IN AN AUSTRALIAN ABORIGINAL.

By S. A. SMITH, M.B., Ch.M., *Senior Demonstrator in Anatomy, University of Sydney.*

IN the skeleton of an adult female Australian aboriginal unearthed near Sydney, N.S.W., there occurs a numerical reduction of the carpus on both sides, only seven bones being present in each wrist. This is due to the fusion of the semilunar and cuneiform bones, forming an os lunato-triquetrum on each side.

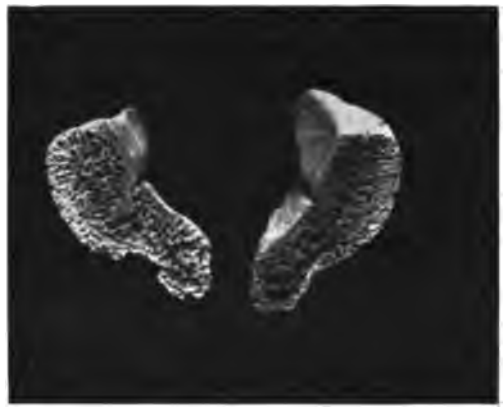


FIG. 1.

The fusion is almost complete. The proximal surface shows a smooth continuous articular surface, and neither on it nor on the palmar and dorsal surfaces of the bone can any indication be seen of the line of fusion of its two elements. The distal surface, however, shows a well-marked cleft running dorso-ventrally but not notching either edge of this surface (see fig. 1). This plainly indicates the line of fusion, so that on this surface one can distinguish from within outwards the articular surface for the os magnum, a small bevel for the unciform, the well-marked cleft and a large articular surface for the unciform. This groove extends into the bone for a distance of 1 mm. only. On coronal section the cancellous tissue of one half of the bone is absolutely continuous with that of the other, the only

indication of the line of fusion in such a section being the cleft running in from the distal surface (fig. 1).

A quite similar condition exists on both sides. There is no trace of any inflammatory or other pathological process. No other abnormality exists in the skeleton of hands or feet.

Derry (*Journ. of Anat. and Phys.*, vol. xli., part i., p. 56) reports three instances of this os lunato-triquetrum in two Soudanese negroes, and refers to two instances described by Elliot Smith (*Anat. Anzeiger*, Bd. xxiii., p. 494) in both wrists of one individual, also a Soudanese negro.

These are the only cases recorded since Pfitzner (*Zeits. f. Morph. u. Anth.*, Bd. ii., p. 650), in his exhaustive work on the human carpus, collected sixteen instances occurring in eleven subjects, and five of these in negroes. Thus there are now on record twenty-three instances of this os lunato-triquetrum, and of these ten are in negroes and two in an Australian aboriginal.

The following is a table of the recorded instances:—

Observer.	Right Carpus.	Left Carpus.	Race and Sex.	Remarks.
Sandifort	Synostosis	Nil	?	One instance. No details.
Soemmering, Wagner, Jourdan, Testut, Humphry	Synostosis	Synostosis	Negro, male	Complete fusion.
Phöbus	Synostosis	Synostosis	European, male	Complete.
Holl	Synostosis	Synostosis	European, male	Complete except for distal grove only.
Anderson	Synostosis ?	Normal	Negro, male	Ditto.
Perrin de la Touche	Normal	Synostosis	European, male	No details.
Paterson	Synostosis	Normal	Negro, male	No details.
Pfitzner	Not examined	Synostosis	European, male	Fusion incomplete, involving *dorsal* third only.
Pfitzner	Synostosis	Normal	European, female	Incomplete, fusion of proximal half only.
Pfitzner	Synostosis	Synostosis	European, male	Incomplete, fusion of proximal half only.
Pfitzner	Synostosis	Synostosis	Negro, male	Incomplete, fusion of proximal portion only.
Elliot Smith	Synostosis	Synostosis	Negro, male	Complete, except for distal groove only.
Derry	Synostosis	Synostosis	Negro, male	Complete, except for distal groove.
Derry	Not examined	Synostosis	Negress	Ditto.
S. A. Smith	Synostosis	Synostosis	Australian aboriginal female	Ditto.

The descriptions given by Humphry, Wagner, Soemmering, Testut, and Jourdan are all from the same specimen in the Museum of the Jardin des

Plantes in Paris. The first case on record was described in 1779 by Sandifort, who merely mentions that he has seen such a fusion but gives no details whatever. The two specimens mentioned by Perrin de la Touche and Paterson, both in 1893, were not described in detail—and Paterson's diagram shows only one aspect of the bone. Of the other instances—those in which the form of the bone was more or less accurately described—four, viz. the cases of Soemmering and Phöbus, showed complete concrescence without any trace of the line of fusion. In Pfitzner's first case, recorded in 1895, and also in two instances he found in the dog, the fusion is limited to the *dorsal* third only of the adjacent surfaces of semilunar and cuneiform bones. In all the other cases, fifteen in number, the line of fusion is represented by a cleft more or less deep, ranging from less than 1 mm. to more than half the depth of the bones, which is situated *distally* in every case.

In Pfitzner's later cases this cleft is apparently much deeper than in those of other observers, but the difference is one of degree only.

In 1895 Pfitzner (*Morph. Arb.*, Bd. iv., p. 550), from the examination of the only specimens then in his possession—one from a human and two from a dog—was led to believe that the fusion was probably due to the intermediate agency of the epipyramoid ossicle, which is sometimes found between the dorsal portions of the semilunar and cuneiform bones. Since then, however, he was constrained to relinquish this view (*Zeitschrift f. Morph. u. Anth., loc. cit.*), as all his other specimens showed the fusion to involve the proximal and not the dorsal portion of the surfaces of contact of the two bones. It is interesting to note that in all the other cases, where there is some indication of the line of fusion, this line is always present on the distal side only.

Such a fusion as the one under discussion does not occur normally in any mammalian carpus. In Pteropus, as Anderson has pointed out, a somewhat similar condition is present, the three bones of the proximal row being fused into one bone, a very deep cleft, which involves the whole of the depth of the bone except the proximal portion existing between the navicular portion on the one hand and the lunato-triquetral portion on the other.

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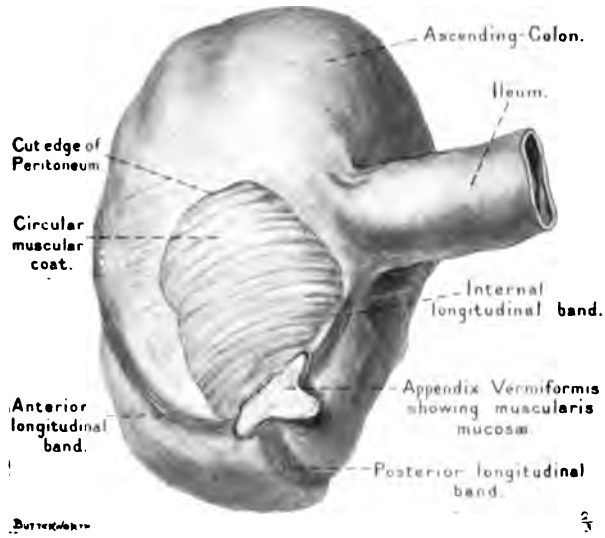
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ANATOMICAL NOTES.

Small Vermiform Appendix. By Sydney R. Scott, M.S., F.R.C.S.

The specimen was removed *post mortem* from the body of a man age 36, who died from ruptured liver. No operation had been performed on the abdomen. There were no signs of abnormal adhesions in the abdominal cavity, and no signs of inflammation, recent or old, in the appendix region.



At the time of removal the appendix measured 7·5 mm. After dissection of the muscular walls the appendix measured 9 mm. There was no meso-appendix and no special appendicular artery.

The position of the cæcum was the right iliac fossa. The dimensions of the cæcum were of the normal average.

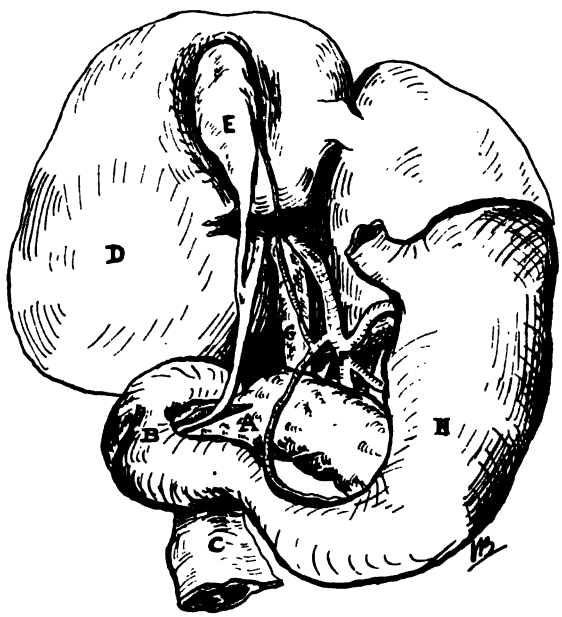
Direction of the Ileo-Cæcal Aperture. By Ralph Thompson, M.B., F.R.C.S.

Several specimens of fœtal, infantile, and adult cæca were shown at the Anatomical Society, which all exhibited a downward direction of the orifice

between the two segments of the ileo-cæcal valve. In some of the specimens the direction of the orifice was much more downwards than outwards. In the opened cæcum the fæces passing through the ileo-cæcal orifice were directed towards the outer and lower part of the cæcum. The specimens had all been hardened in formalin, and open and closed orifices were shown.

An Abnormal Form of Duodenum. By Gordon Taylor, M.A., M.B., B.Sc., M.S., F.R.C.S.

The first part of the duodenum was directed downwards and to the right; the second part ran to the right; the third part ascended, and then, curving to the left, passed behind the head of the pancreas and the first part



A, head of pancreas; B, second part of duodenum; C, third part of duodenum; D, right lobe of liver; E, gall bladder; F, cœliac axis; G, portal vein; H, stomach.

of the duodenum. The duodenum appeared to have rotated from right to left around an axis which corresponded to the attachment of the bile-duct to the gut. The head of the pancreas was very poorly developed, and it was suggested that this might have played a part in the production of the anomaly.

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JOURNAL OF ANATOMY AND PHYSIOLOGY

DESCRIPTIONS OF THREE CHINESE BRAINS PRESENTED BY DR F. W. MOTT, F.R.S., TO THE MUSEUM OF THE ROYAL COLLEGE OF SURGEONS.[1]

By E. H. J. SCHUSTER, M.A., D.Sc., *Fellow of New College, Oxford.* (*From the Pathological Laboratory, Claybury Asylum, Essex, and the Department of Comparative Anatomy, University Museum, Oxford.*)

PART I.

I. MATERIAL.

CASE No. I.—Male Chinese, aged 40; occupation, coolie; weight about 8 stone; body well developed; previous illness, chronic bronchitis. P.M.: Right lung consolidated; liver markedly diminished in size, several small cavities in substance all containing liver flukes; Distoma Sinensis? Cause of death, pneumonia.

CASE No. II.—Male Chinese, aged 40; occupation, coolie; weight about 9 stone; previous illness, nil. P.M.: Spleen much enlarged; liver do. Cause of death, malaria.

CASE No. III.—Male Chinese, aged about 40; occupation, coolie; body development fair; died day of admission. P.M.: Old pleurisy; spleen enlarged; kidneys enlarged and congested, capsule strips readily; 6 oz. of semi-purulent fluid in pericardial sac; pericardium thickened, vascular, shaggy; here and there spots of pus. Cause of death, pericarditis.

II. DIMENSIONS OF BRAINS.

(1) *Weight after hardening in 5 per cent. formalin, Membranes removed.*

	Medulla, pons, and cerebellum.	Right hemisphere.	Left hemisphere.
Case No. I.	156 grammes	510 grammes	490 grammes
„ No. II.	194 „	648 „	659 „
„ No. III.	172 „	633 „	631 „

[1] The Council of the Royal College of Surgeons kindly contributed ten pounds towards defraying the expenses of the illustration of this paper.

Total weight.	Pons and cerebellum.	Total weight.	Pons and cerebellum.	Total weight.	Pons and cerebellum.
No. 1 = 1156	: 156.	No. 2 = 1501	: 194.	No. 3 = 1426	: 172.
Ratio 7·4	: 1.	7·7	: 1.	8·3	: 1.

(2) *Sylvian Angle.*

In estimating the angle which the Sylvian fissure makes with the horizontal plane, it is necessary to have some convention by which that plane can be determined. The plane suggested by Cunningham ("Surface Anatomy of the Cerebral Hemispheres," *Cunningham Memoirs*, No. 7, 1892) is that which lies at right angles to the median plane and passes through the most projecting points at the frontal and occipital poles.

Cunningham's Sylvian angle is the angle made by the Sylvian fissure with a transverse plane lying at right angles to the horizontal. For the brains under consideration it is as follows:—

	Right hemisphere.	Left hemisphere.
Brain No. I.	Too much distorted for measurement.	
„ No. II.	64°	70°
„ No. III.	63°	63°

If the plane touching the two lowest points of the temporal lobe is taken as the horizontal plane, then the angle made within by the Sylvian fissure is as follows:—

	Right hemisphere.	Left hemisphere.
Brain No. II.	8°	7°
„ No. III.	11°	12°

It will be noted that the more the Sylvian fissure slopes upwards the smaller will be Cunningham's Sylvian angle and the larger the angle measured in the last-mentioned manner.

(3) *Linear Measurements.*

Three series of linear measurements have been made:

I. *Length of Fissures, Breadth of Gyri, etc.*—These were made with callipers, and consequently represent the shortest distance between the two points named in each case. They will be found scattered through the text.

II. *Depth of Fissures.*—This was ascertained by pulling apart the walls of the fissures and inserting gently the ivory handle of a scalpel on which a scale had been engraved, so that its bluntly rounded end rested on the bottom of the fissure. The distance of the latter from the general surface of the brain could then be read off from the scale. It must, however, be

understood that no great accuracy is claimed for these or indeed for any of the measurements.

These measurements are recorded only on the outline figures, which are intended to act as explanations of the photographs. The numbers which will be found scattered over these drawings give in millimetres the depth of the fissure at the point against which each number stands. It was thought better to record the distances and the depths in different ways, since if both sets had been recorded in the same way, either the text would have become more clumsy, involved, and obscure than it is at present, or the figures would have lost their comparative lucidity.

III. The third series of measurements give the general dimensions of the brains and are recorded in tabular form below. Brain No. I. was considered to be too distorted to be worth measuring.

Greatest Length of Hemisphere projected on Median Plane.

	Right hemisphere.	Left hemisphere.
Brain No. II.	186 mm.	189 mm.
„ No. III.	173 „	173 „

Distance of Sylvian Fissure from Supero-mesial Border.

Distance measured with tape over the surface of the hemisphere from (*a*) the anterior end of the fissure, where the ramus anterior is given off; (*b*) the point at which it branches into the two rami posteriores. In each case the tape was passed over the surface in a transverse plane at right angles to the horizontal (*vide supra*, second definition of horizontal plane, under heading Sylvian angle). The upper point taken was not actually the border, which is difficult to define, but the horizontal surface on which the brain was allowed to rest with its mesial aspect downwards.

	Right hemisphere.	Left hemisphere.
Brain No. II. (*a*)	101 mm.	105 mm.
(*b*)	102 „	103 „
Brain No. III. (*a*)	102 „	101 „
(*b*)	103 „	102 „

Distance measured with a tape along the supero-mesial border from the most projecting point at the frontal pole to (*a*) the place at which the sulcus centralis cuts the border, or, if it fails to cut it, where a line carried along the general direction of the fissure would cut the border; (*b*) the point at which the fossa parieto-occipitalis cuts the border; (*c*) the most projecting point at the occipital pole.

	Right hemisphere.	Left hemisphere.
Brain No. II. (*a*)	142 mm.	139 mm.
(*b*)	212 „	207 „
(*c*)	265 „	252 „
Brain No. III. (*a*)	132 „	149 „
(*b*)	201 „	222 „
(*c*)	248 „	265 „

Distance measured over the lateral surface with a tape from the most projecting point at the frontal pole to (*a*) the point at which the sulcus centralis would, if produced along the line of its general direction, cut the Sylvian fissure; (*b*) the most projecting point at the occipital pole.

	Right hemisphere.	Left hemisphere.
Brain No. II. (*a*)	111 mm.	103 mm.
(*b*)	240 „	253 „
Brain No. III. (*a*)	105 „	103 „
(*b*)	132 „	229 „

III. Nomenclature.

The nomenclature of Gustav Retzius, used in his work *Das Menschenhirn*, has been adopted throughout in the following descriptions except in dealing with the occipital region. Here the names proposed by Elliot Smith (*Anat. Anz.*, Bd. xxiv., p. 436) have been used, since it is usually easier to bring the occipital region into line with his system than with any other.

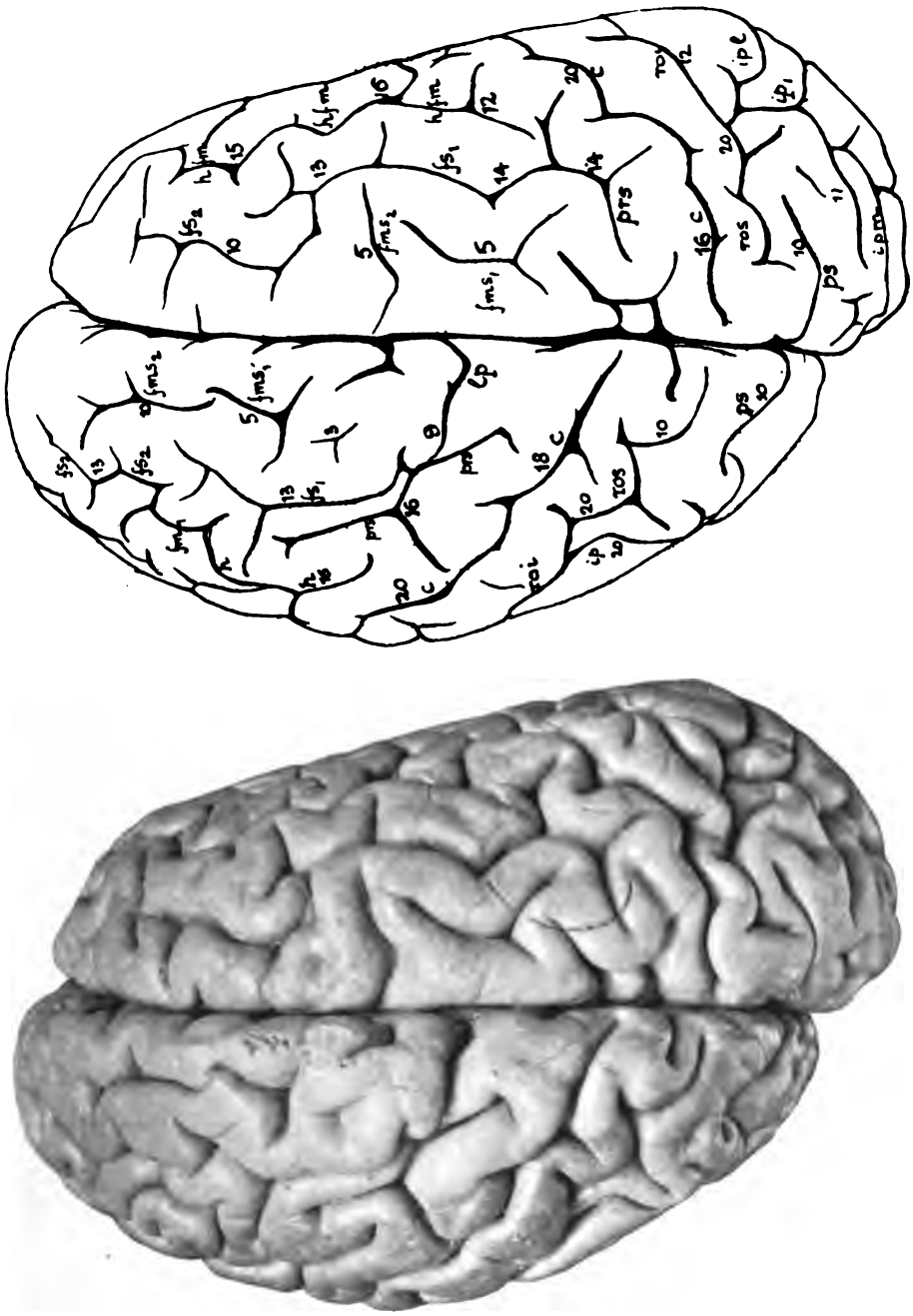
IV. Detailed Descriptions of Fissures and Convolutions.

CHINESE BRAIN No. I.

Right Hemisphere.

Fissures separating Lobes of the Hemisphere.

The *Sylvian fissure* is provided with one anterior ramus (*ra*), 9 mm. in length, which runs upwards and opens below together with the sulcus diagonalis (*d*) into a small lacuna in the upper operculum, through which a portion of the insula may be seen. Occupying the position of a ramus anterior horizontalis is a superficial fissure, which cannot be regarded as the homologue of this ramus, since it does not cut through the operculum. From the posterior wall of the gap in the operculum referred to above, the main stem of the Sylvian fissure (*Fsy*) runs backwards for 50 mm. and



Chinese Brain No. 1. Viewed from above.

(For explanation of figures see p. 374.)

then divides into two rami posteriores, ascendens and descendens; the former (*rpa*), which is 18 mm. in length, lies almost in the same straight line as the main stem; the latter (*rpd*) runs downwards and forwards for 9 mm. The *Sulci subcentrales, anterior* (*sca*) and *posterior* (*scp*), join the main stem of the fissure (*Fsy*), the former midway along its course, the latter just in front of its posterior point of bifurcation.

The *Sulcus centralis* (*c*).—The upper end of this sulcus cuts the supero-mesial border; its lower end reaches to within 5 mm. of the Sylvian fissure. The superior and inferior genua are not conspicuous. The anterior wall is raised up into two well-marked gyri which project backwards and interdigitate with three smaller elevations on the posterior wall.

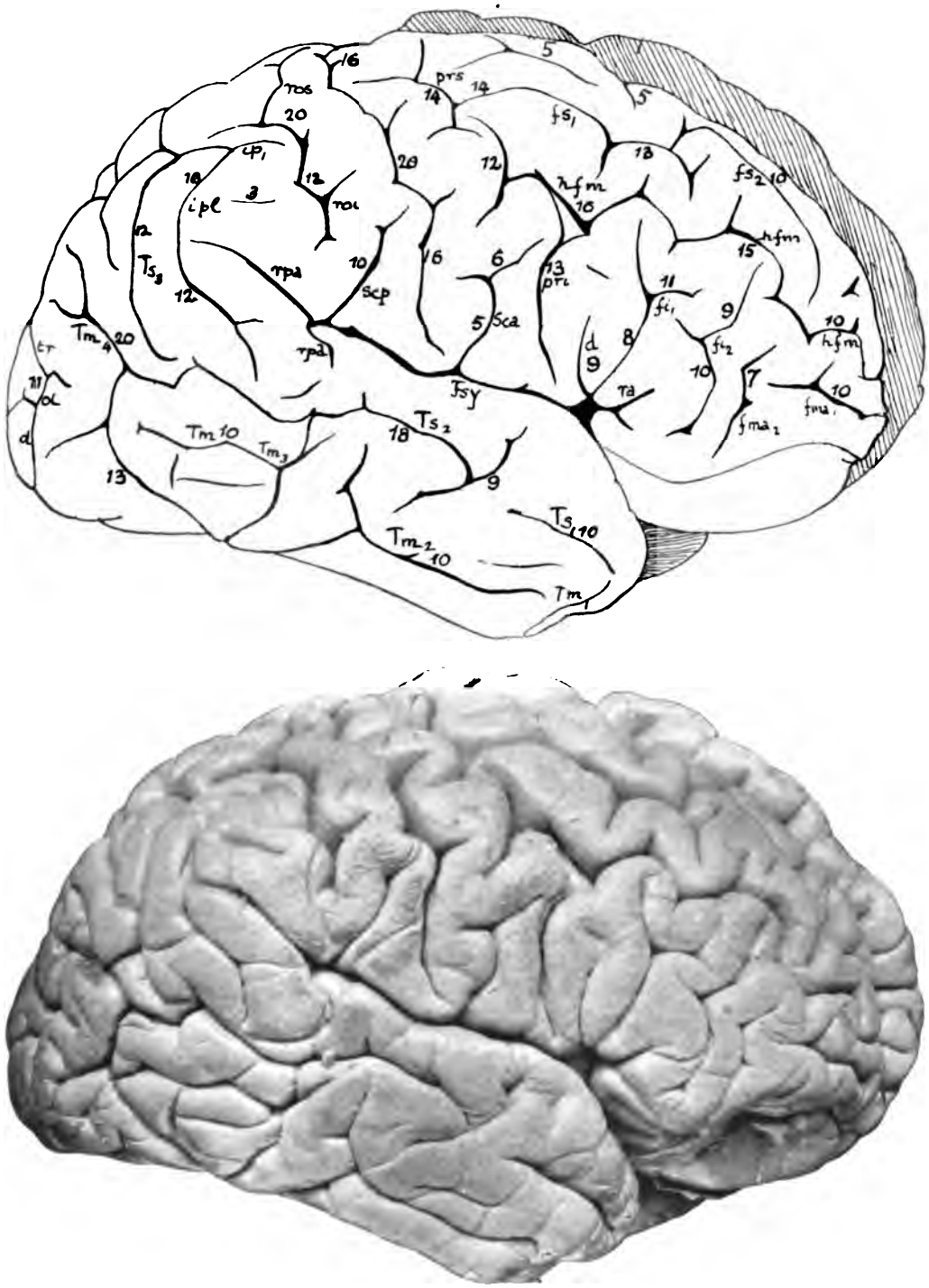
The *Sulcus cinguli* (*sc*) originates immediately below the genu of the corpus callosum, and runs first round its anterior end and then more or less parallel to its upper border till it reaches a point above the splenium, where it turns upwards to end at the supero-mesial border. Close to its posterior extremity it is superficially connected with the sulcus parietalis superior (*ps*), which runs on to the mesial surface of the hemisphere. It is traversed by two deep annectant gyri (an_1 and an_2), the points at which these occur being each marked by a double bend. It gives off one or two insignificant branches towards the border of the hemisphere.

The Calcarine System of Fissures.

The *Arcus intercuneatus*, although almost completely sunk into the fossa parieto-occipitalis (*fpo*), is just visible from the surface, and the *Incisura parieto-occipitalis* extends on to the outer face of the hemisphere for 23 mm., ending within 5 mm. of the sulcus interparietalis (*ip*). The *Sulcus paracalcarinus* is hidden in the fossa, but the *Sulcus limitans præcunei* may be seen forming the anterior boundary of the arcus intercuneatus; it ends in a bifurcation, the outer limb of which runs outwards parallel to the incisura 3–6 mm. in front of it. The superficial extent of the fossa parieto-occipitalis on the median surface is about 33 mm.

The *Sulci calcarinus* (*cal*) and *intrastriatus mesialis* (*im*) form a continuous fissure, which is joined by the fossa parieto-occipitalis 36 mm. from its anterior end and is crossed at two points (an_1 and an_2) by the two deep gyri cuneo-linguales; it ends posteriorly near the occipital pole in a widespread bifurcation measuring 22 mm. between the ends of the two limbs.

The *Sulcus collateralis* (*col*) is an unbroken fissure which runs at first upwards to a point immediately below the anterior end of the sulcus calcarinus and then turns downwards, ending in a bifurcation 23 mm. from



Chinese Brain No. 1. Outer aspect. Right hemisphere.

the occipital pole. In its posterior half it gives off a short upward branch which anastomoses with the sulcus limitans areæ striatæ inferior (*lsi*) and a downward branch.

THE FRONTAL LOBE.

The Principal Sulci.

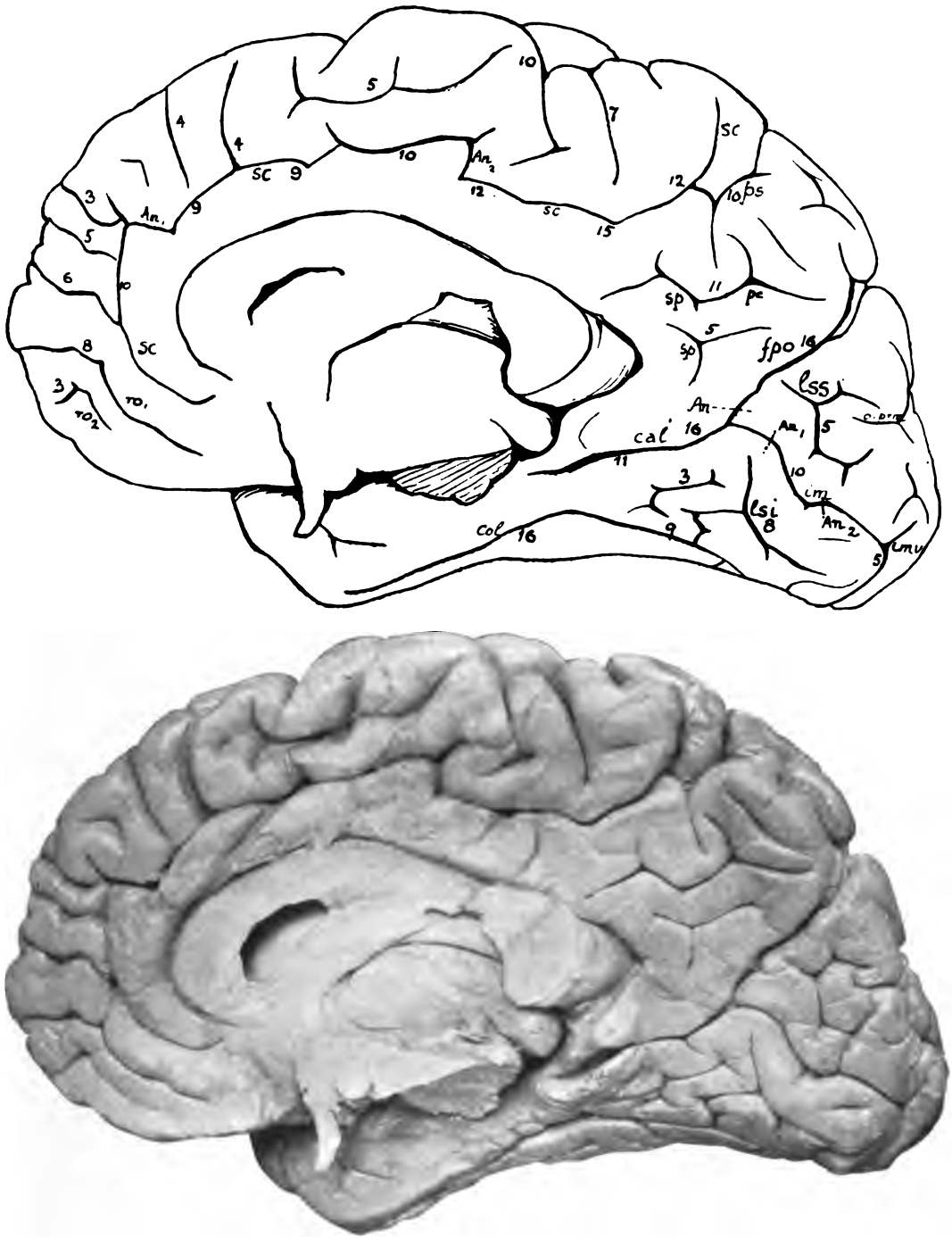
Sulcus præcentralis superior (*prs*), which is 36 mm. in length, from about the middle of its course sends a branch backwards towards the sulcus centralis. Its inner end is bounded by a curved gyrus, itself delimited by a fissure which sends two vertical branches downwards into the lobulus paracentralis.

Sulcus præcentralis inferior (*pri*) at its lower end reaches to within 5 mm. of the Sylvian fissure. It runs upwards and slightly backwards for 35 mm., and near its upper end is connected over a deep annectant gyrus with a long and sinuous fissure (*hfm*) which almost completely bisects longitudinally that part of the frontal lobe which lies in front of the anterior central convolution. The posterior part of this fissure may perhaps be regarded as the ramus horizontalis of the sulcus præcentralis inferior, and its anterior part as an exceedingly well-developed sulcus frontalis medius. It is 76 mm. long from its anterior extremity to the point at which it joins the vertical crosspiece in which it ends behind.

Sulcus frontalis superior (*fs*) is divided into two considerable segments, of which the posterior (fs_1) is the more important; this is 46 mm. long; it ends behind in the sulcus præcentralis superior and in front in a cross-piece, 16 mm. behind which it gives off a short, downwardly directed branch. The posterior end of the anterior segment (fs_2) is superficially connected with the portion of the fissure lying behind it, and its total length is some 35 mm.

Sulcus frontalis inferior (*fi*).—As if to compensate for the high state of development reached by the sulcus frontalis medius (*hfm*), the sulcus frontalis inferior is somewhat reduced, consisting only of two completely separated triradiate segments. The posterior of these (fi_1) is made up of two upper limbs, measuring respectively 12 and 9 mm. in length, and a lower limb 16 mm. long, which stretches downwards between the sulcus diagonalis (*d*) and the ramus anterior ascendens (*ra*) of the Sylvian fissure. The anterior segment (fi_2) has a posterior limb 6 mm. in length and two anterior limbs, measuring 19 mm. and 16 mm. respectively. The upper of these is connected by a superficial groove with the fissure *hfm*.

Sulcus fronto-marginalis is divided into two segments: the inner one (fma_1), which lies just above the superciliary margin, is 30 mm. long; the



Chinese Brain No. 1. Right hemisphere. Inner aspect.

outer one (fma_2) is 26 mm. long, and runs parallel to the anterior segment (fi_2) of the sulcus frontalis inferior, about 7 mm. in front of it.

Gyri and Smaller Sulci.

Gyrus centralis anterior is very well developed. In its upper region its average width is about 15 mm.; in its lower region, where its anterior boundary is formed by the sulcus præcentralis inferior (*pri*), it forms a rectangular piece about 35 mm. in length and 20 mm. in breadth. A large portion of this area is subdivided longitudinally by the sulcus subcentralis anterior (*sca*), which runs upwards and slightly forwards from the Sylvian fissure for 17 mm. and there ends in a crosspiece. The anterior central convolution is connected by narrow, superficial gyri with each of the three horizontal convolutions of the frontal lobe, and beneath the lower end of the sulcus centralis with the posterior central convolution.

Lobulus paracentralis, which is of an average breadth of 27 mm., is incompletely separated from the mesial surface of the gyrus frontalis superior. It is cut into by two fissures which run downwards and slightly backwards from a previously described sulcus which curves round the upper end of the sulcus præcentralis superior (*prs*).

Gyrus frontalis superior on its mesial aspect has an average breadth of 21 mm., and its surface is marked with many shallow and irregular fissures, two of which, lying in the neighbourhood of the frontal pole, may be classed as sulci rostrales (ro_1 and ro_2); of these the upper one is 36 mm. in length and is connected superficially with the sulcus cinguli. On the lateral aspect two regions may be distinguished bounded below by the two segments of the sulcus frontalis superior (fs_1 and fs_2). The posterior of these has an average width of about 25 mm., and is infolded by two segments of the *Sulcus frontalis mesialis* (fms_1 and fms_2); the one, a slightly curved sagittal fissure 29 mm. long giving off a short, inwardly directed branch, and the other, 23 mm. long, and placed transversely. The anterior region measures only about 13 mm. in breadth.

Gyri frontalis medius and *frontalis inferior* are very incompletely divided from one another and will be considered together. The long fissure (*hfm*), which has been identified as the sulcus frontalis medius, combined with the ramus horizontalis of the sulcus præcentralis inferior, completely separates off on the upper side a strip of cortex, measuring 11–15 mm. in breadth, except at the point immediately in front of the sulcus præcentralis superior (*prs*), where it bulges out to a breadth of about 30 mm. This strip is cut into from above by the two downward branches of the sulcus frontalis superior (*fs*), and is connected by a narrow gyrus lying just

below the sulcus præcentralis superior with the gyrus centralis anterior. The remainder of the middle frontal, together with the whole of the inferior frontal convolution, form an area 35–40 mm. broad posteriorly, which is continued forwards as a much narrower strip, lying just above the superciliary margin. The broad portion contains, in addition to the fissures already described, a *Sulcus diagonalis* (*d*) 15 mm. long, which lies 5–10 mm. in front of the lower end of the sulcus præcentralis inferior (*pri*), and opens into the same gap in the operculum as the ramus anterior ascendens (*ra*) of the Sylvian fissure.

The Orbital Surface.

Sulcus olfactorius is 39 mm. in length.

Sulcus orbitalis consists of an outer limb 32 mm. in length and slightly curved, which gives off near the middle of its course an inwardly and backwardly directed branch 23 mm. long. To the inner side of the outer limb are three irregularly placed fissures, of which the middle one lies more or less sagittally and is the largest, being 28 mm. long.

THE PARIETAL, OCCIPITAL, AND TEMPORAL LOBES.

The Principal Sulci.

Sulci retrocentrales (*roi* and *ros*) are united to form a continuous fissure 54 mm. long, the bifid inner end of which lies 11 mm. distant from the supero-mesial border, while its outer extremity reaches to within 13 mm. of the Sylvian fissure. Twenty mm. from the former a short, backwardly directed branch is given off, and 10 mm. from the latter another which points upwards and forwards. Well-marked interdigitating gyri lie in the lower half of the fissure, of which one may possibly be regarded as an annectant.

Sulcus interparietalis (*ip*) is not connected with the sulcus retrocentralis. Almost immediately behind its anterior termination it gives off a long, downwardly directed branch (*ipl*), which passes within 7 mm. of the ramus posterior ascendens of the Sylvian fissure (*rpa*) and ends 40 mm. from its starting point, and 4 mm. short of the sulcus temporalis superior (*Ts*). Twelve mm. behind the point at which this branch is given off the sulcus interparietalis is connected with the ramus ascendens (Ts_3) of the last-named fissure, and 10 mm. behind this again it bifurcates, sending one branch inwards for 21 mm. and forming, by means of the other, which is traversed by a deep annectant gyrus, a junction with its own posterior or occipital segment. The latter is quite conventional in form, consisting of a straight sagittal fissure 33 mm. long, which ends behind in the *Sulcus transversus* of Ecker (*tr*), and in front sends its ramus mesialis (*ipm*)

inwards for 17 mm. and a shorter branch outwards to join the anterior segment (ip_1).

Sulcus transversus (*tr*) runs inwards from the point of junction for 11 mm. and outwards for the same distance. At its outer extremity it joins a fissure which may be called the *Sulcus occipitalis lateralis* (*ol*). The latter consists of a curved anterior limb 15 mm. long, which branches posteriorly, the upper branch being also curved and measuring 20 mm. from end to end, and the lower branch straight and 12 mm. long.

There is no distinct *Sulcus lunatus*, and the stria of Gennari stops at the occipital pole.

Sulcus temporalis superior (*Ts*) is divided into three segments: the anterior (Ts_1), which lies near the temporal pole, is 34 mm. long; the middle segment (Ts_2) starts in front in an oblique crosspiece, with which, however, it is only in superficial connection, and runs almost straight backwards for 52 mm., where it unites with the fourth segment of the sulcus temporalis medius (Tm_4); the third segment (Ts_3) consists of a ramus ascendens which is 37 mm. long and united above with the anterior portion (ip_1) of the sulcus interparietalis.

Sulcus temporalis medius (*Tm*) is divided into four irregular segments, of which the third and fourth anastomose with the middle segment of the sulcus temporalis superior (Ts_2).

Sulcus temporalis inferior consists of three obliquely placed portions, of which the two anterior lie almost entirely on the tentorial aspect. They are both bifid in front, and measure from the point at which they fork to their posterior ends approximately 25 mm. The posterior piece situated on the tentorio-lateral margin is 22 mm. long.

Gyri and Smaller Sulci.

Gyrus centralis posterior for the upper part of its length is somewhat convoluted and measures only 6 mm. across, but as one passes towards the Sylvian fissure it gradually widens out to about three times this breadth. It is cut into from below by the *Sulcus subcentralis posterior* (*scp*), which runs upwards for 18 mm. from the Sylvian fissure, and ends in an oblique crosspiece. This divides the lower portion of the gyrus into two longitudinal strips, of which the anterior is continuous beneath the sulcus centralis (*c*) with the gyrus centralis anterior, and the posterior beneath the sulcus retrocentralis inferior (*roi*) with the gyrus marginalis. The upper end is continuous with the lobulus paracentralis and the gyrus arcuatus anterior.

Præcuneus measures approximately 37 mm. in length by 27 mm. in

breadth; it is somewhat irregularly fissured. The most anterior of its fissures, which stretches into it for 22 mm. from the lateral surface and makes a superficial connection with the sulcus cinguli, is the sulcus parietalis superior (*ps*). The larger irregular and smaller triradiate fissures, which lie behind this, represent together the *Sulcus præcunei* (*pc*) and the *Sulcus subparietalis* (*sp*), while in addition to these there is a smaller, straight cleft lying near to the superior border.

Lobulus Parietalis Superior.

Since the sulcus cinguli fails to reach the lateral surface, the *Gyrus arcuatus anterior* is represented only by a strip of cortex about 13 mm. broad, which connects the gyrus centralis posterior with the *Gyrus arcuatus medius*. The latter is large and well developed, stretching outwards for 37 mm. and measuring approximately 35 mm. in a sagittal direction. It is marked with the following fissures:—(1) *Sulcus parietalis superior* (*ps*). This lies near the anterior boundary, and is 22 mm. long from its outer extremity to the point at which it turns over the supero-mesial border on to the præcuneus. (2) A small H-shaped fissure lying on that border immediately behind this point. (3) The inwardly directed branch from the anterior portion of the sulcus interparietalis. (4) A shallow depression lying between (1) and (3).

The apex of the gyrus arcuatus medius is continuous with the gyrus marginalis between the anterior end of the sulcus interparietalis and the sulcus retrocentralis.

Gyrus arcuatus posterior forms a rectangular figure measuring 36 mm. in length and 22 mm. in breadth. Its anterior and posterior and external boundaries are formed as usual by the sulcus interparietalis and the sulcus transversus of Ecker. The incisura parieto-occipitalis almost completely separates from it an anterior strip about 12 mm. broad, into which the sulcus limitans præcunei runs. In its posterior division lie a small sagittal fissure 10 mm. long and the bifid anterior end of the *Sulcus occipitalis paramesialis*. The last-named fissure starts near the occipital pole, and runs forwards by a somewhat irregular course along the supero-mesial border; it sends a short branch downwards into the cuneus and ends in front as described.

Lobulus Parietalis Inferior.

Gyrus marginalis measures some 27 mm. across at its broadest point, and its apex lies 35 mm. from the junction of the two posterior rami of the Sylvian fissure. Its posterior boundary is formed by the branch (*ipl*) of

the sulcus interparietalis, which completely separates it from the gyrus angularis. Lying on its upper half is a short, straight fissure 12 mm. long.

Gyrus angularis.—Since the ramus ascendens (Ts_3) of the sulcus temporalis superior is separated from the main fissure, but joins the sulcus interparietalis above, the usual arrangement of this gyrus is reversed, in that its two limbs are continuous at its lower and not at its upper extremity. The upper 30 mm. of the anterior limb have a uniform width of 10 mm., but at its lower end it opens out to a breadth of 18 mm. The posterior limb is roughly triangular in form, and the greater part of its posterior boundary is formed by a straight fissure, 20 mm. long, lying somewhat obliquely and superficially connected above with the posterior segment of the sulcus interparietalis (ip_2).

Cuneus is triangular, its two anterior sides measuring 33 mm. (upper side) and 42 mm. (lower side), while its posterior side is 46 mm. long. An irregular-shaped *Sulcus limitans areæ striatæ superior* (*lss*) is present, and in addition to this a branch runs down on to the surface of the cuneus from the *Sulcus occipitalis paramesialis* (*o.prm*).

Gyrus temporalis superior is narrowest in the neighbourhood of its middle point, where it measures only 9 mm. across; both in front of and behind this it increases gradually in breadth, reaching 18 mm. in front and 20 mm. behind. It is cut into by the tranverse fissure which lies at the anterior end of the second segment of the sulcus temporalis superior (Ts_2), immediately in front of which it communicates with the gyrus temporalis medius. The ramus posterior descendens (*rpd*) of the Sylvian fissure also runs downwards and forwards into it.

Gyrus temporalis medius, the lower boundary of which is somewhat fragmentary, attains its maximum breadth of 22 mm. at a distance of 54 mm. from the temporal pole. The upper posterior branch of Tm_2 almost traverses it at this point, and immediately behind it communicates with the gyrus temporalis inferior. The region behind this point of communication, which is 7–14 mm. wide, is completely separated from all that lies in front of it by the anastomosis which the third segment of the sulcus temporalis medius (Tm_3) establishes with the second segment of the sulcus temporalis superior (Ts_2).

Gyrus temporalis inferior and *Gyrus fusiformis* form a very irregularly fissured region on either side of the tentorio-lateral margin.

Gyrus lingualis is of the typical shape. It is 11 mm. wide where it communicates with the gyrus hippocampi and gradually attains a breadth of 28 mm., which it reaches immediately behind the point of junction of the fossa parieto-occipitalis (*fpo*) and the sulcus calcarinus (*cal*); at this breadth approximately it remains in its posterior region. In its anterior

half is an insignificant fissure of about 18 mm. in length, and in its posterior half there is a well-developed *Sulcus limitans areæ striatæ inferior* (*lsi*), which runs more or less parallel to the sulcus intrastriatus mesialis (*im*), at a distance of 7–10 mm. from it, and anastomoses with the sulcus collateralis (*col*).

Left Hemisphere.

Fissures separating Lobes of the Hemisphere.

Sylvian fissure.—As in the right hemisphere, there is a ramus anterior ascendens (*ra*) which stretches upwards for 17 mm. from its point of junction with the main stem, while the position of the ramus horizontalis is occupied by a shallow fissure which does not cut through the operculum. The main stem (*Fsy*) itself stretches backwards from the opening of the ramus anterior for 63 mm., and then forks into the ramus posterior ascendens (*rpa*) and the ramus posterior descendens (*rpd*), each 10 mm. long, which point sharply upwards and downwards.

Sulcus centralis (*c*) at its inner end cuts the supero-mesial border, while its outer end reaches to within 5 mm. of the Sylvian fissure. The genua are only very slightly marked. The anterior wall of the fissure is raised up into three broad gyri of which the middle one is the most strongly developed, and these interlock with the two small gyri on the posterior wall.

Sulcus cinguli (*sc*) starts 8 mm. in front of the genu of the corpus callosum. It diverges from the upper border of the latter till it reaches a point 44 mm. from its anterior end, where it is separated from it by a distance of 20 mm.; then, as it runs backwards, after approaching to within 13 mm. of it, it again gradually diverges, till it cuts the supero-mesial border 10 mm. behind the sulcus centralis, giving off one short, backwardly directed branch just before doing so. Ten mm. from this branch a superficial connection is established with one of the fissures of the præcuneus. Another fissure, which curves round the anterior end of the sulcus cinguli and sends off five branches towards the border, may possibly be regarded as an anterior segment.

Calcarine System of Fissures.

The *Arcus intercuneatus* and its limiting sulci cannot be identified with certainty. The *Fossa parieto-occipitalis* (*fpo*) stretches for only 12 mm. on the lateral surface, but is continued outwards for another 10 mm. by a superficial groove; it gives off, on the mesial surface, close to its anterior end, a very short, forwardly directed branch, and is joined from behind by

a shallow sulcus 14 mm. long near to the supero-mesial border. From this border to its point of union with the sulcus calcarinus (*cal*) it measures 33 mm. Its lower end is crossed by the gyrus cunei.

Sulcus calcarinus (*cal*) itself appears to be very short, but this may be due principally to the distortion of the hemisphere. It makes a very well-marked angle with the *Sulcus intrastriatus mesialis* (*im*), from which it is separated by the deep *Gyrus cuneo-lingualis anterior*. From this point the sulcus intrastriatus mesialis (*im*) runs downwards and backwards to the occipital pole in a line which is almost mathematically straight, and then, 35 mm. from its anterior end, joins its ramus verticalis (*imv*). Immediately before this point it is crossed by the deep *Gyrus cuneo-lingualis posterior*. The ramus verticalis has an upper limb 10 mm. long and a lower limb 14 mm. long.

Sulcus collateralis (*col*) forms a continuous fissure which is joined in front by the *Sulcus rhinencephali inferior* (*sri*) and behind by one of the segments of the sulcus temporalis inferior. Furthermore, it is connected by a straight shallow fissure joining it 52 mm. from its anterior end with the sulcus limitans areæ striatæ inferior (*lsi*).

FRONTAL LOBE.

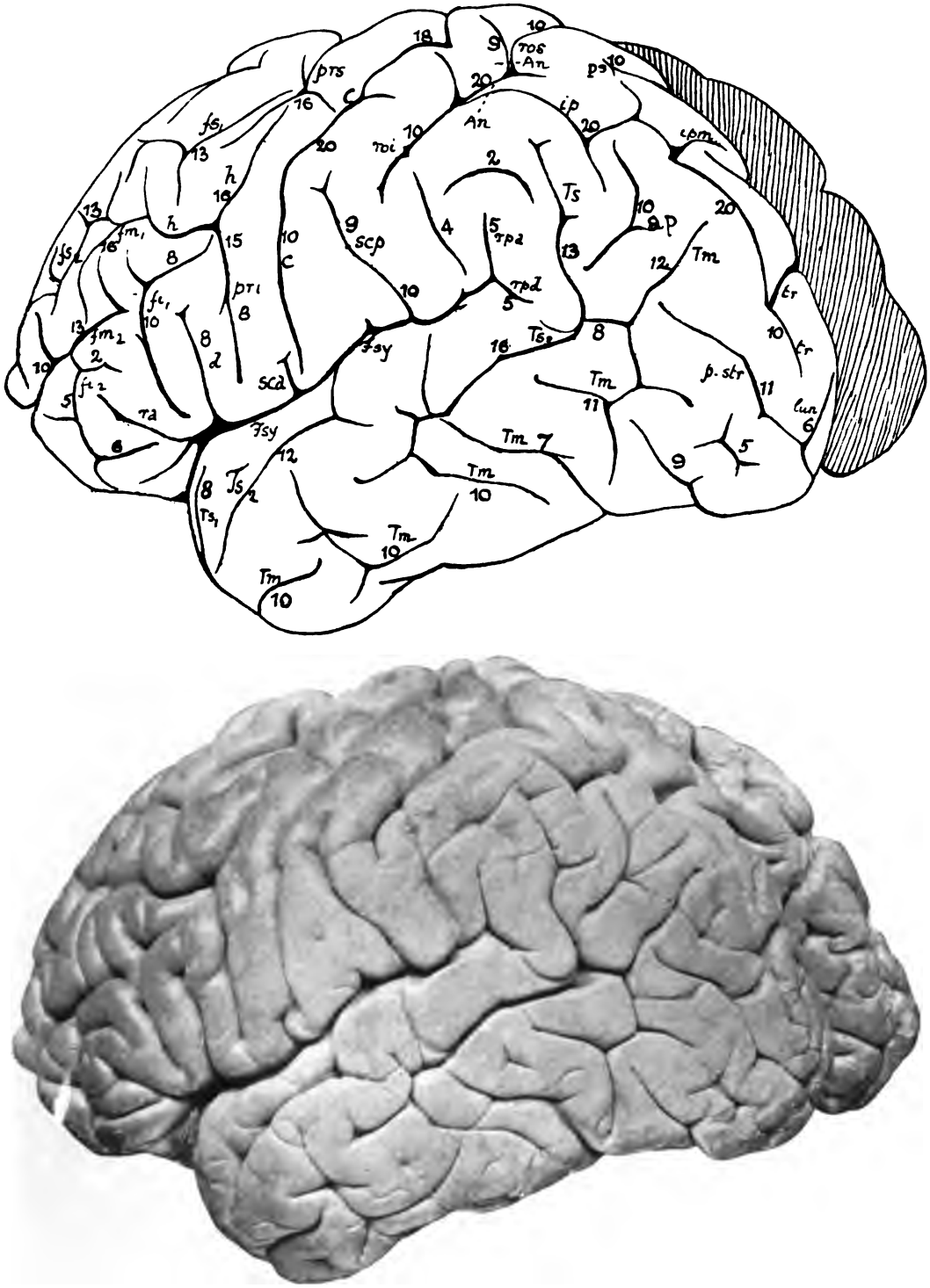
The Principal Sulci.

Sulcus præcentralis superior (*prs*) is a curved fissure with its lower extremity bifid. Its upper end lies 14 mm. from the supero-mesial border and 25 mm. from its point of bifurcation. The posterior of its two lower branches is superficially connected with the sulcus centralis.

Sulcus præcentralis inferior (*pri*).—The lower end of this fissure lies 6 mm. from the Sylvian fissure (*Fsy*). From this point it runs straight upwards for 30 mm. and there joins a curved fissure (*h*), which may be regarded as its ramus horizontalis.

Sulcus frontalis superior is divided into two segments. The posterior (fs_1) is superficially connected at its posterior extremity with the sulcus præcentralis superior (*prs*), and 35 mm. in front of this point ends by dividing into two small branches; another branch, 13 mm. long, is given off in a downward direction, 11 mm. behind this. The anterior segment (fs_2) is exceedingly irregular in shape, sending off several short branches both upwards and downwards; its length, measured between its two extreme points, is 49 mm.; the most posterior of its downward branches is connected with the sulcus frontalis medius (*fm*).

Sulcus frontalis medius (*fm*) is divided into two segments. The posterior (fm_1) is continuous behind with the ramus horizontalis (*h*) of the



Chinese Brain No. 1. Left hemisphere. Outer aspect.

sulcus præcentralis inferior. The anterior (fm_2) is a straight fissure 35 mm. long, which ends behind in a short crosspiece and in front joins the sulcus fronto-marginalis. It sends off two short upward branches.

Sulcus frontalis inferior (fi) is somewhat reduced, as in the right hemisphere; it consists of two triradiate pieces of which the posterior (fi_1) is the larger. This sends off one arm to terminate close to the junction of the vertical and horizontal portions of the sulcus præcentralis inferior, and another downwards in front of the sulcus diagonalis (d), while the third is directed upwards and lies parallel to and 7 mm. behind the terminal crosspiece of the anterior segment of the sulcus frontalis medius (fm_2). The anterior segment (fi_2) consists of a short upward limb connected with the latter, and two longer downwardly directed limbs of which the anterior joins the sulcus fronto-marginalis.

Sulcus fronto-marginalis is divided into two segments of which the inner one lies along the superciliary margin and is 29 mm. in length; the outer one is 27 mm. long.

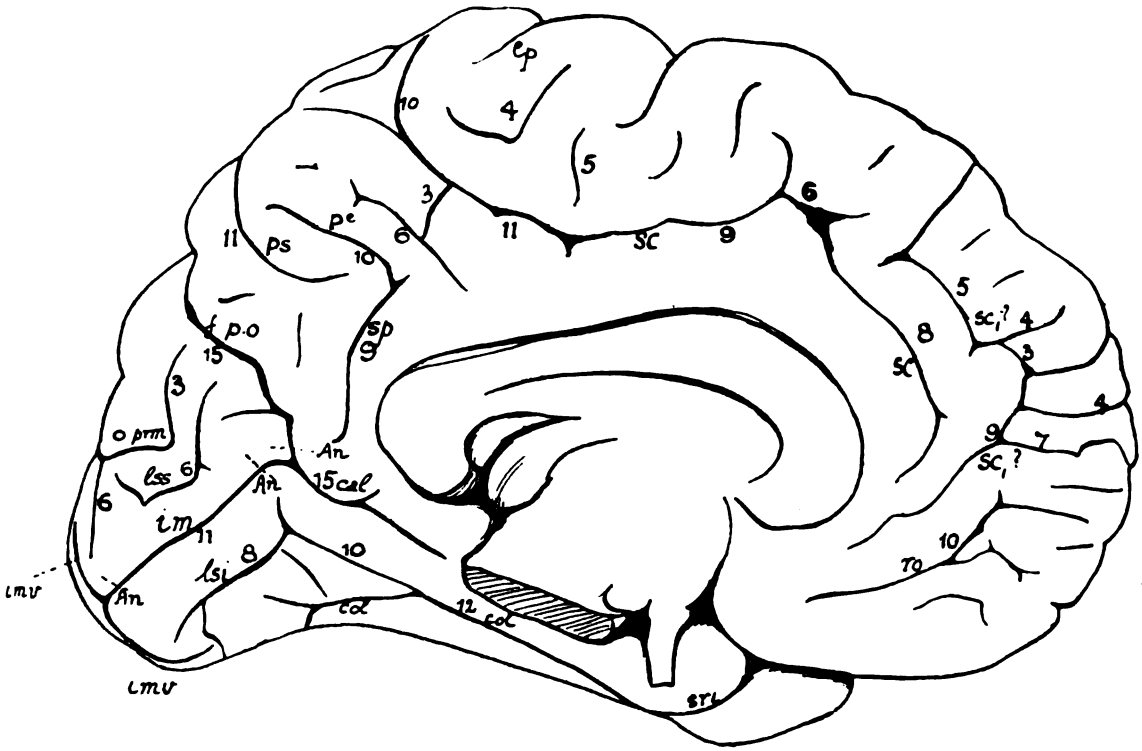
Gyri and Smaller Sulci.

Gyrus centralis anterior is more or less regular in form and measures from 10 to 17 mm. in breadth; its broadest region is situated some 45 mm. from its upper end, and it is here cut across by the lower posterior branch of the sulcus præcentralis superior (*prs*) On the inner side of that fissure it communicates with the gyrus frontalis superior, and on the outer side of it with the gyrus frontalis medius; beneath the sulcus præcentralis inferior (*pri*) it is continuous with the gyrus frontalis inferior. A *Sulus subcentralis anterior* (*sca*), 6 mm. long, runs up into it just in front of the lower end of the sulcus centralis.

Lobulus paracentralis is not definitely bounded in front. It is marked by two or three shallow fissures and one deeper one (*lp*) which cuts through the supero-mesial border and stretches for 15 mm. on to the lateral surface immediately in front of the upper end of the sulcus præcentralis superior.

Gyrus frontalis superior on the mesial aspect measures 19–30 mm. in breadth. The principal fissure (sc_1?) occurring in it has been described in the account of the sulcus cinguli. In addition to this there is a *Sulcus rostralis* 32 mm. long, which sends two branches forwards in the neighbourhood of the anterior end.

On the lateral aspect the average width of the gyrus is about 25 mm. Near its posterior end it is almost completely cut across by the fissure (*lp*), and in front of this lie the segments of the *Sulcus frontalis mesialis* (*fms*). Of the latter two are of considerable size, the posterior (fms_1) being



Chinese Brain No. 1. Left hemisphere. Inner aspect.

triradiate, and the anterior (*fms*$_2$), a straight sagittal sulcus 27 mm. in length, which ends in front in a crosspiece, and sends off one small, inwardly directed branch. The gyrus frontalis superior communicates with the gyrus frontalis medius between the two segments of the sulcus frontalis superior.

Gyrus frontalis medius.—Although, owing to the poor development of the sulcus frontalis inferior, its lower boundary is somewhat indeterminate, it would not be incorrect to say that the breadth of the gyrus is about 25 mm. Its surface is much fissured, since the ramus horizontalis of the sulcus præcentralis inferior (*h*) and the sulcus frontalis medius (*fm*) are very well developed, and, in addition to these, three well-marked branches stretch downwards from the sulcus frontalis superior.

Gyrus frontalis inferior is about 30 mm. broad posteriorly, but becomes narrower towards its anterior end. The arrangement of the fissures which lie in it is very similar in plan to that which obtains in the corresponding part of the right hemisphere. Besides those fissures which have already been described there is a *Sulcus diagonalis* (*d*), which runs upwards from the Sylvian fissure for a distance of 21 mm.

Orbital Surface.

Sulcus olfactorius is 30 mm. long.

Sulcus orbitalis consists of a curved outer portion 16 mm. long, from the middle of which a branch 23 mm. long runs inwards and backwards. Eleven mm. from its inner end this branch is connected with a sigmoidally curved groove running inwards and forwards, and lying in front of it between the groove and the outer curved limb are two straight fissures, obliquely disposed, 28 and 11 mm. in length.

PARIETAL, OCCIPITAL, AND TEMPORAL LOBES.

The Principal Sulci.

Sulci retrocentrales (*ros* and *roi*) form a continuous fissure stretching from the supero-mesial border to a point 22 mm. distant from the Sylvian fissure. This is traversed 20 mm. from its inner end by a deep annectant gyrus, and sends off a short forwardly directed branch above this and one backwardly directed below it.

Sulcus interparietalis (*ip*) joins the sulcus retrocentralis 22 mm. above the lower extremity of the latter, but complete continuity is prevented by an annectant gyrus sunk only very slightly below the surface, which crosses it at its posterior extremity; from this point it runs an uninterrupted

course backwards to end by joining the sulcus transversus of Ecker (*tr*); 34 mm. from its posterior end it gives off its ramus mesialis (*ipm*), which runs inwards for 14 mm., and a short way in front of this another inwardly directed branch 10 mm. in length; 25 mm. from the anterior end of the fissure a branch, 10 mm. long, is sent off in an outward and backward direction.

Sulcus transversus of Ecker (*tr*)—The inner and outer lines of this fissure are joined together in the form of a rather sharp curve, so that while the former runs inwards for 15 mm., the latter runs almost directly backwards for about the same distance.

Sulcus lunatus (*lun*) is a very slightly curved transverse fissure, 23 mm. long, which lies about 10 mm. in front of the occipital pole. The stria of Gennari extends to within 4 mm of its lip.

Sulcus præstriatus (*p.str*) runs forwards and upwards for 43 mm. from the sulcus lunatus, which it joins posteriorly.

Sulcus temporalis superior (*Ts*) is divided into three segments. The anterior (Ts_1) is a slightly curved fissure 17 mm. long, lying in the neighbourhood of the temporal pole. The middle one (Ts_2) runs backwards in a gentle curve for 35 mm., it then turns abruptly upwards after sending off a shallow backward branch, and its posterior extremity is superficially connected with the Sylvian fissure. The posterior segment (Ts_3) is by far the largest of the three; it first runs backwards for 52 mm. and then turns upwards almost at right angles to its previous course to form a ramus ascendens 36 mm. long. It is connected at its bend with the posterior segment of the sulcus temporalis medius (*Tm*).

Sulcus temporalis medius (*Tm*) is split up into five irregularly placed segments.

Sulcus temporalis inferior consists of one principal segment, 50 mm. long, the anterior end of which lies some distance from the temporal pole, and of four smaller and more irregular portions lying to the outer side of and behind this.

Gyri and Smaller Sulci.

Gyrus centralis posterior, in the region bounded in front by the sulcus retrocentralis, measures not more than 15 mm. across; below this it is continuous behind with the gyrus marginalis, so its breadth cannot be determined. At its upper end it joins the lobulus paracentralis and the gyrus arcuatus anterior. The *Sulcus subcentralis posterior* (*scp*) stretches up into it from the Sylvian fissure for 29 mm.

Præcuneus measures about 40 mm. from back to front. Lying near its

anterior border, 8 mm. from the sulcus cinguli (*sc*) and connected with that fissure by a superficial furrow, is a straight sulcus, 21 mm. long. Behind this is another shaped like an inverted L, the vertical limb being 21 mm. long and the horizontal limb 22 mm. long. Together these two fissures may represent the *Sulcus subparietalis* (*sp*) and the *Sulcus præcunei* (*pc*). The *Sulcus parietalis superior* (*ps*) also stretches on to the præcuneus for 25 mm., lying behind the last described sulcus, and in addition to these there are present three insignificant depressions.

Lobulus Parietalis Superior.

Lobulus parietalis superior is divided into three *gyri arcuati*. The anterior of these is imperfectly separated from the gyrus centralis posterior, but its posterior boundary is clearly defined by the upper end of the sulcus retrocentralis superior (*ros*). It surrounds the incisura cinguli and stretches inwards from the supero-mesial border for 15 mm.

Gyrus arcuatus medius has an average breadth of about 25 mm. and stretches inwards and forward for 37 mm. In addition to this its apex is prolonged into a narrow convolution which traverses the posterior end of the sulcus interparietalis (*ip*) slightly below the surface, and thus connects it with the gyrus marginalis. Its fissures consist of (1) the *Sulcus parietalis superior* (*ps*), which runs for 24 mm. on the lateral surface. (2) A short forwardly directed branch from the sulcus interparietalis. (3) A sagittal groove lying to the outer end of the sulcus parietalis superior. The sulcus retrocentralis superior (*ros*) in front, and the ramus mesialis (*ipm*) of the sulcus interparietalis behind, leave in each case only narrow passages along the median border, by which it communicates on the one hand with the gyrus arcuatus anterior and on the other with the gyrus arcuatus posterior.

Gyrus arcuatus posterior forms a fairly regular rectangular figure, measuring 33 mm. in length and 18 mm. in breadth. The arrangement of its boundaries is quite conventional.

Lobulus Parietalis Inferior.

Gyrus marginalis is confluent with the *Gyrus angularis*. The ramus ascendens of the sulcus temporalis superior runs parallel to the ramus posterior ascendens of the Sylvian fissure (*rpa*), at a distance of about 14 mm. behind it. A curved sulcus 15 mm. long lies transversely above the end of the latter; while behind the former, forming the posterior boundary of the gyrus angularis, is another curved fissure (*ap*), 23 mm. long.

Cuneus is triangular, its upper, lower, and posterior boundaries being respectively 33, 40, and 49 mm. long. Two fissures mark its surface. The *Sulcus occipitalis paramesialis* (*o.prm*) consists of a V-shaped anterior portion measuring 23 mm. from end to end, which joins posteriorly a straight piece 24 mm. long. The latter lies obliquely across the supero-mesial border, its anterior half running on to the lateral surface and terminating a short way behind the sulcus transversus of Ecker, while its posterior half runs downwards on the mesial surface towards the occipital pole. The apex of the anterior V-shaped portion lies 12 mm. from the sulcus instrastriatus mesialis (*im*).

The *Sulcus limitans areæ striatæ superior* (*lss*) lies half-way between this and the sulcus intrastriatus mesialis (*im*). It is 22 mm. long and ends behind in a short crosspiece.

Gyrus lingualis is shaped as the right hemisphere. The principal sulcus lying in it is the *Sulcus limitans areæ striatæ inferior* (*lsi*). This is a straight fissure 24 mm. long, lying parallel to the sulcus intrastriatus mesialis (*im*), at a distance of 11 mm. from it; its anterior end is connected with the sulcus collateralis (*col*) by another straight fissure. In the posterior region of the gyrus there is present a small sulcus bifurcated at either end; and there is, in the anterior half, a small simple fissure 10 mm. long.

Gyrus temporalis superior on its upper surface is raised up into one large "transverse gyrus of Heschl." On its lateral surface in its anterior region it is imperfectly bounded below by the two anterior segments of the sulcus temporalis superior (*Ts*); behind these its breadth varies from 13 to 19 mm.

The remaining gyri of the temporal lobe are almost impossible to describe, since their boundaries are so uncertain, owing to the fact that the inferior and middle temporal sulci are broken up into so many and such irregular segments.

EXPLANATION OF FIGURES.

Brain I.

Both hemispheres from above	Fig. 1
Right hemisphere, lateral aspect	,, 2
,, ,, mesial aspect	,, 3
Left hemisphere, lateral aspect	,, 4
,, ,, mesial aspect	,, 5

ABBREVIATIONS USED IN FIGURES.

Frontal Lobe with its Bounding Fissures.

Sylvian fissure—main stem, *fsy.*
,, ,, ramus posterior ascendens, *rpa.*
,, ,, ramus posterior descendens, *rpd.*
,, ,, ramus anterior ascendens, *ra.*
,, ,, ramus anterior horizontalis, *rh.*
Sulcus centralis, *c.*
Sulcus præcentralis superior, *prs.*
Sulcus præcentralis inferior, *pri.*
Sulcus præcentralis inferior, ramus horizontalis, *h.*
Sulcus frontalis superior, *fs.*
Sulcus frontalis medialis, *fms.*
Sulcus frontalis medius, *fm.*
Sulcus frontalis inferior, *fi.*
Sulcus frontomarginalis, *fmr.*
Sulcus radiatus, *r.*
Sulcus diagonalis, *d.*
Sulcus cinguli, *sc.*
Sulci rostrales, *ro.*
Sulcus subcentralis anterior, *sca.*

Parietal Lobe.

Sulcus retrocentralis superior, *ros.*
Sulcus retrocentralis inferior, *roi.*
Sulcus subcentralis posterior, *scp.*
Sulcus interparietalis, *ip.*
Sulcus interparietalis, ramus mesialis, *ipm.*
Sulcus interparietalis, lateral branches, *ipl.*
Sulcus transversus of Ecker, *tr.*
Sulcus parietalis superior, *ps.*
Sulcus subparietalis, *sp.*
Sulcus præcunei, *pc.*

Occipital Lobe.

Sulcus lunatus ("Affenspalte"), *lun.*
Sulcus occipitalis paramesialis, *o.prm.*
Sulcus intrastriatus lateralis (occipitalis superior), *il.*
Sulcus præstriatus (prælunatus), *p.str.*
Fossa parieto-occipitalis, *fpo.*
Sulcus limitans præcunei, *l.pr.*
Incisura parieto-occipitalis, *ipo.*
Sulcus calcarinus, *cal.*
Sulcus intrastriatus medialis (retrocalcarinus), *im.*
Sulcus intrastriatus medialis, ramus verticalis, *imv.*
Sulcus limitans areæ striatæ superior, *lss.*
Sulcus limitans areæ striatæ inferior, *lsi.*
Arcus intercuneatus, *arc.int.*

Temporal Lobe.

Sulcus collateralis, *col.*
Sulcus temporalis superior, *Ts.*
Sulcus temporalis medius, *Tm.*
Sulcus temporalis inferior, *Ti.*

TOOTH-VESTIGES AND ASSOCIATED MOUTH-PARTS IN THE *MANIDÆ*.

By H. W. Marett Tims, M.A., M.D., F.L.S., *Professor of Biology in the Royal Veterinary College, and of Zoology, Bedford College (University of London).*

Our knowledge of the tooth-genesis in the Edentata is so scanty, and such facts as are known so disconnected, that any contributions, however small, which may help to fill in the deficiencies, are of value; consequently, I make no apology for the publication of observations based upon the examination of a single fœtus. And further, apart from the question of tooth-genesis, it will be seen in the sequel that other points come to light which are of considerable interest.

The specimen upon which these observations are based was kindly given to me by Dr W. L. H. Duckworth, by whom it was, I believe, originally received from Dr Hose of Borneo, and I desire to express my grateful thanks for the opportunity afforded me of examining it.

From the fact that the fœtus was obtained from Borneo, and from the external characters of the fœtus itself, I believe it to belong to the species *Manis javanica*.

Max Weber, in his classical monograph "Beiträge zur Anatomie und Entwicklung der Genus·Manis" (6), has pointed out the particular interest and importance attaching to the knowledge of the tooth-genesis in attempting to solve the vexed questions relating to the phylogeny and inter-relationships of the various families of Edentates.

In 1874 C. S. Tomes demonstrated the existence of an enamel organ in an Armadillo (*Tatusia peba*) (5). Ten years later Pouchet and Chabry published an account of the tooth-genesis in *Orycteropus* (2), and this was succeeded in 1892 by a paper of a similar nature by Ballowitz (1), dealing with the enamel organs in *Dasypus*; but, so far as I am aware, the only fœtal specimens of Manis which have previously been examined in this connection are those described by Max Weber (*loc. cit.*). They consisted of three specimens of *M. tricuspis* and two of *M. javanica*. The three specimens of the former had total lengths of 7·6 cm., 17 cm., and 30 cm. respectively, while of the two latter the length of only one is given, viz. 9 cm.; in the other the gill-slits were visible, and this specimen was therefore probably too young to show any evidence of tooth development.

The examination of this material in Max Weber's hands yielded purely negative results.

The same specimens were subsequently re-examined by Röse (3, 4), who discovered certain downgrowths of the dental lamina which he interpreted as tooth-vestiges. Of these he found two pairs in the lower jaw: one pair in each of the older specimens of *M. tricuspis*, towards the anterior end, which apparently represents the same tooth; the other pair being situated rather more posteriorly in the lower jaw of the older *M. javanica* (9 cm.). In this



FIG 1.—Section through the upper and lower lips of the right side, showing the upper lip overlapping but separate from the lower lip.

same fœtus Röse draws attention to a spindle-shaped swelling of the dental epithelium along the edge of the upper jaw immediately behind the opening of Stenson's duct, which he interprets in a similar manner. Beyond this swelling he finds no other trace of a tooth-vestige in the upper jaws of any of the material. The conditions found in the specimen under consideration seem to bear out the correctness of Röse's opinions, which at first sight seem to be based on very slender evidence.

Before describing the tooth-vestiges, I would draw attention to certain interesting peculiarities found in the associated mouth-parts, since they afford a clue to the formation of the elongated tubular mouth present in these animals.

This fœtus had a head length of 6·1 cm., and a total length, measured circumferentially from the tip of the snout to the tip of the tail, of 25·3 cm.; it is therefore intermediate between Max Weber's two oldest specimens of *M. tricuspis*. Examination was made by means of serial transverse sections. Through the anterior part of the jaws the lips are distinct and separated from one another by the cleft of the mouth, the upper overlapping the lower as seen in fig. 1. Their surfaces, like that of the dental edges of the jaws, are covered by a large-celled parenchymatous epithelium, which alters in character at the outer margin of the lips, passing



FIG. 2.— Similar section, but on a slightly more posterior plane, showing the union of the two lips by the "cellular band" passing from the buccal cavity to the exterior.

somewhat abruptly into the more flattened, slightly cornified epithelium of the outer surface of the face (fig. 1).

Very soon, however, the cleavage between the lips disappears, the large-celled epithelium of the two blending together and forming a broad band passing obliquely outwards and downwards and extending between the buccal cavity and the outer surface, thus completely separating the muscular and connective tissues of the two lips from one another (fig. 2). In other words, there is here no true cheek, the apparent cheek being but the two lips united by their surfaces throughout the greater part of their extent, being free from one another at the anterior end only to form the small and somewhat circular mouth. This condition obtains through a considerable

portion of the elongated jaws. Nearing the posterior end, *i.e.* behind the opening of Stenson's duct, this cellular band ceases to reach the other surface (fig. 10), and passing still more posteriorly, it keeps on gradually receding from the surface until it disappears, and the true cheek, as seen in other mammals, comes into existence, but not until the posterior ends of the jaws are nearly reached. So far as I am aware, this condition is unique among mammals, though no doubt it is present in all Edentates with a similar form of mouth.

The point is of considerable interest as tending to show that these old-

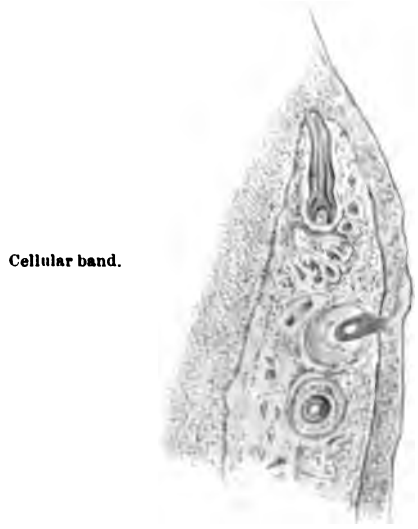


Fig. 3.—Section through the upper part of cheek, showing hair growing into the outer part of the "cellular band."

world Edentates have probably been derived from ancestors in which the elongated mouths were capable of being widely opened. Correlated with this tubular form of mouth there is a considerable diminution in the size and strength of the mandible and a disappearance of the teeth. The question arises, which of these conditions has been antecedent to the other? Has the feebleness of the jaw allowed the lips to become united, by not opening the mouth? or has the fusion of the lips prevented the opening of the mouth, and, by disuse, brought about the reduction of the bone and of the teeth? Unfortunately, there is practically no palæontological evidence to throw any light upon the matter. From a consideration of the South American Edentates, both recent and fossil, and from what appears

to be a fact, viz. that the more distinctly and perfectly tubular the mouth, the more degenerate the teeth, it is conceivable that the union of the lips, to whatever cause this may have in the first instance been due, has been the primary and chief contributing cause of the correlated degenerations. It can be readily understood that with the adoption of a termite dietary a fusion of the lips with each other at the sides would be of advantage in preventing the escape of the food.

That this cellular band stretching through the lateral wall of the buccal



FIG 4.—Section through right half of hard palate and gum, showing the projecting "tongue-scraper" (*x*).

cavity was originally, like the mouth, part of an involution of the external layers, is further borne out by the direction of the hair follicles. Many of these, as shown in fig. 3, are pointing towards the cellular band with but a very slight inclination outwards. The direction is such that it seems probable that many of the hairs, even if they develop much beyond the stage seen in this embryo, will never protrude beyond the surface, but remain as it were embedded in the substance of the buccal wall. This condition seems to indicate that with the union of the lips a portion of what once was superficial skin-tissue has also become secondarily involuted, a hair-bearing portion of the skin now being involved in the more external part of this parenchymatous band. It seems as if the protrusion of the lips in front

had mechanically effected an inward suction of the lateral apposed portions. One can produce the same condition by strongly protruding the lips to make a small circular aperture and drawing in one's breath, which has the effect of involuting the cheek. Such suction on the part of a pangolin would not only produce the same mechanical effect, but it would materially assist in drawing in the termites on to the tongue and into the mouth.

The epithelium which covers the tongue and the surface of the jaws has a clear, refringent appearance in its most superficial layers which is due to a process of keratinisation. This is the more noticeable where the upper jaw merges into the palate, and also over the palate itself. In these situations there is a series of curious, sharply pointed, horny projections. These extend throughout what may be roughly termed the premolar regions.

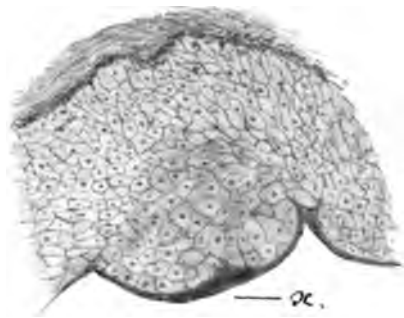


FIG. 5. - Right upper gum (highly magnified), showing slight downgrowth of cornified cells; first indication of the formation of the "scraper"

These projections are in the form of elongated cones with their acute apices pointing almost directly inwards towards the middle line, but with a slight inclination downwards towards the dorsum of the tongue. They are quite isolated the one from the other, and are not the more elevated portions of a continuous ridge; neither do they lie one immediately behind the other, some being nearer the median line, others further from it. The cornified processes have open bases which are implanted obliquely in the epithelium. One of these projections is represented in fig. 4.

They appear to commence as a slight thickening of the superficial layers of the epithelium, the cells becoming more granular and keratinised and invading the deeper layers (fig. 5). I cannot speak with certainty of this stage, but I believe the representation here given is that of a very early stage in the formation of one of these processes. Of the later stage, as shown in fig. 5, there can be no doubt. Here the superficial cells of the

epithelium are deeply invading the subjacent layers, but as yet the apex of the projection is not liberated, as is the case when fully formed.



FIG. 6.—Later stage of the same, showing superficial cells invading obliquely the subjacent epithelium.

It was at first difficult to arrive at any conclusion as to the use of these processes, but on discussing their nature with Dr Gadow, he made the suggestion that they might be of the nature of "tongue-scrapers." The tongue, when covered with termites, is withdrawn into the mouth; and when



FIG. 7.—Lower jaw. Ingrowth of epithelium in outer incisor region. ? Tooth-vestige of Röse.



FIG. 8.—The deepest extremity of the same. Three sections behind that of fig. 7. The intervening sections show the downgrowth to be continuous.

protruded again, to obtain further supplies, the projections would scrape and clean the tongue and thus keep the insects in the mouth. This suggestion seems to be quite probable, certainly I can offer no other.

Turning now to the existence of tooth-vestiges, of which previous evidence is, as has been said above, very scanty. Towards the anterior end

of the lower jaw there is a well-marked downgrowth of the dental lamina. Fig. 7 shows the connection of this with the surface, while fig. 8, taken from the second section further back, represents its deep extremity. It is difficult accurately to localise this tooth-vestige, for such I take it to be; but from the relation of the opposing surface of the upper jaw to the pre-maxillo-maxillary suture, I am inclined to think it must represent an outer incisor. I think there can be but little doubt that it represents a later stage in the development of the same vestige as Röse has drawn attention to in *M. tricuspis* (7·6 cm.). With this exception I find no trace of teeth in

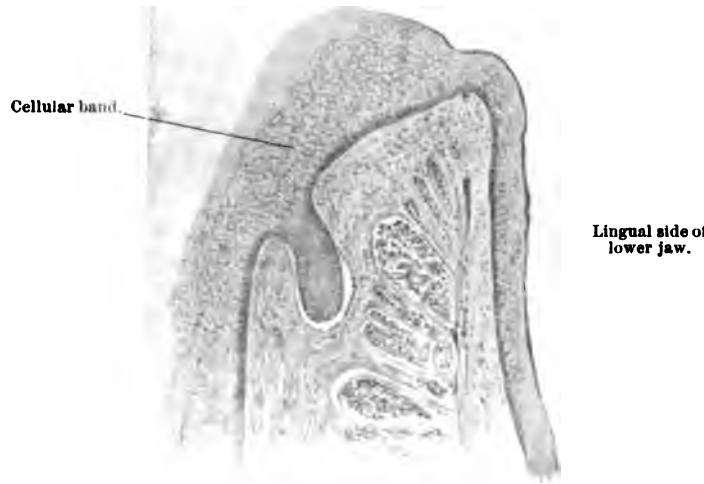


FIG. 9.—Section through lower "jaw area," with an ingrowth from the cellular band forming a tooth-vestige (?).

either jaw until the region of the opening of Stenson's duct, and here there are numerous ingrowths of the buccal epithelium into the lower jaw area. These ingrowths spring from the band of large-celled tissue which runs through the cheek as previously described. Some of these sink into the lateral aspect, others into the alveolar margin of the connective tissue of the jaw area. I use the term "jaw area" advisedly, since from the great diminution in the size of the jaw itself, it has so far receded from the surface that the tooth-vestiges have ceased to have any connection with it, and are therefore merely embedded in the connective tissues; as is well seen in fig. 9, in which one of these downgrowths is represented, highly magnified. I have been able to make out no less than fourteen independent downgrowths. While most of them tend to spring rather from the lateral

aspect of the jaw area, others arise from the summit, just where this is opposed to a corresponding part of the upper jaw. In some instances three or four downgrowths may be seen springing from the epithelium in the same section; they are quite independent of one another. Consequently, I do not think that they can be regarded as belonging to different dentitions; but their appearance in the same section is due chiefly to the minute size and crowded condition of the vestiges, the alteration in the relation of parts brought about by the diminution in the size of the jaw itself, and possibly, no doubt, due in part to a slight obliquity of the section.



FIG. 10.—Section through lower "jaw area," slightly posterior to fig. 9. The "cellular band" has now lost its connection with the surface. Three tooth-vestiges, the top one showing a dental papilla (?).

Fig 10 shows the relative position of one of these vestiges which gives the appearance of an enamel organ, and in fig. 11 the same vestiges are seen under a high magnification. Again, in another there appears to be evidence of calcification, the minute mass having a slender, peg-like appearance; its position and condition are shown in figs. 12 and 13. The enamel organ and the calcified (?) vestige are both found about the middle of the series of downgrowths, the anterior and posterior members of the series being merely epithelial downgrowths. The series does not extend quite as far back as the posterior limit of the hard palate. These facts appear to be of some importance, and will be referred to subsequently.

In the upper jaw there are *three* separate and distinct downgrowths of the epithelium covering the surface, one of which is shown in fig. 14 and



FIG. 11.—The same vestiges more highly magnified.

indicated by the letter *m*. It may very justly be considered that these do not afford sufficient justification for regarding them as tooth-vestiges. They



FIG. 12.—A similar section still more posterior (nearing the hinder margin of hard palate), showing more tooth-vestiges, the lowest one containing a small calcified (?) peg.



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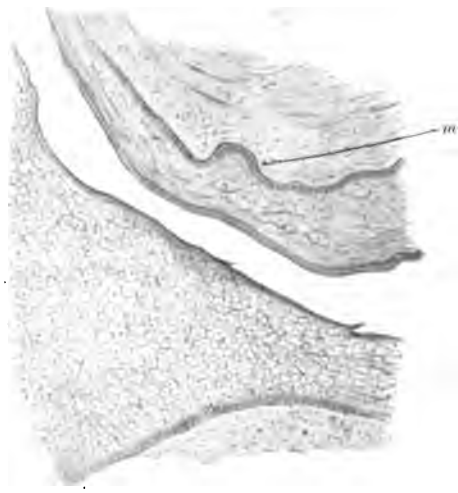


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2. Some of these structures arise from the alveolar margin of the jaw

area, while others spring from its outer surface. Thus, if they were hair follicles, some of the resulting hairs would fringe the alveolar margin, while others would grow *outwards into the substance of the cheek.*

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Assuming then that these are tooth-vestiges, the results of the foregoing remarks may be thus summarised :—

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If, instead of thinking of a bony traction epiphysis, the earlier stage of the cartilaginous or precartilaginous meso-dermal thickening of a tendon as it passes round a projecting knob or bend is postulated, it will give a good working explanation of the mechanism of all these structures.

It is best to take concrete examples which are quite familiar, and to see whether any deductions justified therein can be used as generalisations for traction epiphyses as a class.

Taking then the knee-joint, it is seen that almost the whole of the dorsal musculature of the thigh gains an insertion into the tibia or preaxial bone of the leg a little beyond (distad) the joint, and that, as the knee-joint is gradually bent in a ventral direction, this musculature (the quadriceps extensor cruris) becomes more and more strained over the projecting distal end of the femur. This is the condition found in the Amphibia and lower reptiles, and if the hind limb of a lizard, such as Sphenodon or Iguana, be examined, it will be noticed that the extensor tendon, where it is turning round the knee and where the pressure is chiefly applied against the femur, is of a different texture and less distinctly fibrous than elsewhere. In other words, the tendon is, owing to intermittent pressure, taking on a higher type of histological structure and becoming chondrified. In these lizards it must be remembered the thigh runs out nearly at right angles to the trunk, and the knee is by no means so strongly flexed as in birds or mammals.

In some of the higher lizards and in the Crocodilia chondrification is more extensive and may be succeeded by ossification, while in birds and mammals bony patellæ are the rule. Speaking broadly, it may be said that

the development of the patella varies directly with the amount of flexion allowed at the knee-joint, although the absence of a patella in the Anura, and its cartilaginous condition in most marsupials, are exceptions to this generalisation, since in both these orders the knee is strongly flexed.

Whenever a patella is present there is always, so far as my observations go, a certain length of the original dorsal musculature between it and the

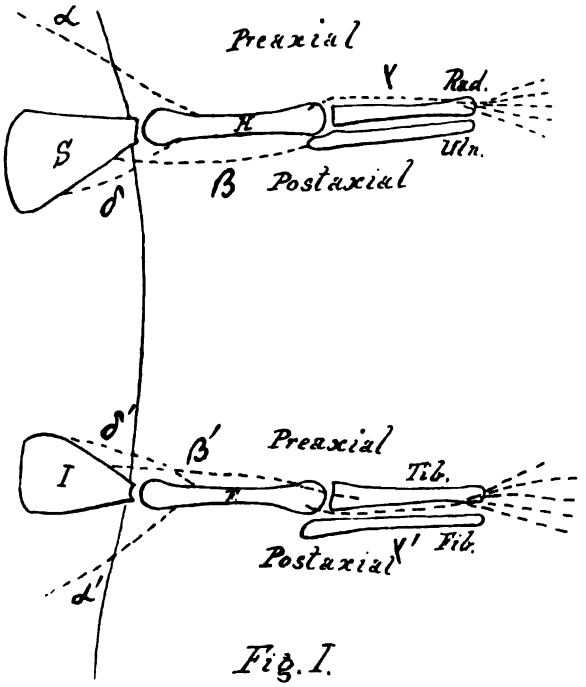


Fig. I.

To show the "looking-glass" symmetry of the muscles of the fore and hind limb from the dorsal aspect.

α, trapezio-deltoid; α', gluteus maximus; β, triceps (long head); β', rectus femoris; γ, extensors of wrist and hand; γ', extensors of ankle and foot; δ, teres major and subscapularis: δ', ilio-psoas.

insertion into the tibia, forming a ligamentum patellæ, and this is due to the great dorso-ventral bulk of the distal end of the femur, as well as to the fact that no apophysis grows up from the tibia toward it. This record of the patella is one of a sesamoid structure pure and simple.

In contrasting the knee with the elbow of an amphibian or lizard, the same bending in a ventral direction is seen; at first slight, though, in higher forms, becoming more marked and accompanied by the same stretching of the dorsal musculature round the distal end of the humerus; but,

whereas in the hind limb this musculature is inserted into the preaxial bone (tibia), in the fore limb it reaches the postaxial (ulna).

It may be noticed in explanation of this that in the proximal segments of the fore and hind limbs there is a looking-glass symmetry, and that in each case the dorsal vertebro-humeral or vertebro-femoral musculature (α, α', fig. 1), consisting of the cephalo-humeral muscle (trapezius and deltoid) in the arm and the ectogluteus (gluteus maximus) in the leg, is preaxial in the former and postaxial in the latter. The long proximal extensors (triceps β and quadriceps β') are postaxial in the arm and preaxial in the thigh. The long distal extensors of the digits (γ, γ') are preaxial in the arm, coming as they do from the external condyle; while in the leg they are postaxial, rising in amphibians, reptiles, and most mammals from the external condyle of the femur.

In addition to these there is another dorsal muscular mass (δ, δ') in each limb which crosses the long proximal extensor ventrally and is attached to the humerus or femur a little distance from its proximal end. This in the fore limb is the equivalent of the teres major, and its forward (cephalic) continuation the subscapularis, while in the hind limb it is the ilio-psoas.

To return to the elbow: the attachment of the triceps to the proximal end of the dorsal surface of the ulna (postaxial bone) is accompanied by the growth of a projection which does not occur in the tibia (preaxial bone). This is the base of the olecranon process, and is a small process in the reptiles where the elbow is little bent, but is much larger in mammals where the bending is sharper.

The upgrowth of this olecranon, it must be remembered, is not primarily an apophysis, since I have shown that in the lizard Varanus there is a definite pressure epiphysis taking in the whole of the upper (proximal) articular surface of the ulna (see "Pressure Epiphyses," *Journ. of Anat.*, vol. xxxix. p. 410), and I have recently found the same thing in the ulna of a young skink lizard. The olecranal upgrowth is therefore only an apophysis in the higher vertebrates, in which, for some reason, the upper pressure epiphysis of the ulna is suppressed.

Another point of difference in the mechanism of the elbow and knee is that the dorso-ventral size of the distal end of the humerus is much less than that of the femur, possibly correlated with the fact that in the reptiles the flexion of the knee is greater than that of the elbow, and so the tibia articulates more with the ventral side of the distal end of the femur than the ulna does with that of the humerus. These two points of difference result in the sesamoid of the elbow being formed quite close to the olecranon, while in the knee it is some distance from the tibia.

With the increased flexion of which the elbow is capable in the mammals, the olecranal upgrowth, which is now a true apophysis, since the proximal pressure epiphysis of the ulna is merged with the shaft, increases in height and presses so closely on the sesamoid structure that at a very early stage in the development of the individual the two cartilaginous structures apparently coalesce. I say apparently, because it is probable that there is a slight perichrondrial septum between the olecranon and the sesamoid structure, or, as it has now become, the traction epiphysis, and this is quite enough to check the ossification of the shaft of the ulna from extending into the epiphysis.

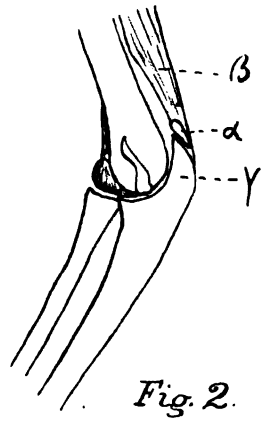


Fig. 2.

Elbow of Iguana lizard to show the olecranon apophysis.

γ, growing up in front of the sesamoid bone; α, developed in the triceps β.

For the presumption that this is the case I depend on the observation of Dr Jenkins, who has recorded a specimen of an 18 mm. human embryo in which the developing epiphysis of the great trochanter is separated from the diaphysis of the femur by a thin line of perichondrial tissue. This specimen, through the kindness of Professor A. Robinson, I have been able to show to the Anatomical Society again, since it is of such importance as a link in my chain of argument.

It seems reasonable to believe that what is true for the great trochanter will, with our improved methods of embryological research, be shown to hold for other traction epiphyses.

The fact that the line of junction between the body and epiphysis of the mammalian olecranon is oblique is due, I think, to the fact that the olecranon grows up in front of (ventral to) the original sesamoid structure. This I have seen it doing in the Iguana lizard (see fig. 2).

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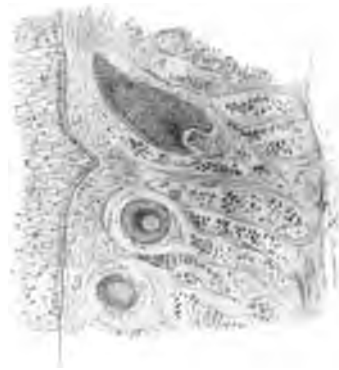


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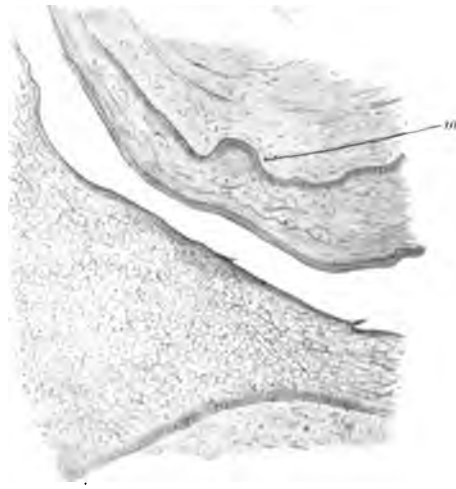


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the development of the patella varies directly with the amount of flexion allowed at the knee-joint, although the absence of a patella in the Anura, and its cartilaginous condition in most marsupials, are exceptions to this generalisation, since in both these orders the knee is strongly flexed.

Whenever a patella is present there is always, so far as my observations go, a certain length of the original dorsal musculature between it and the

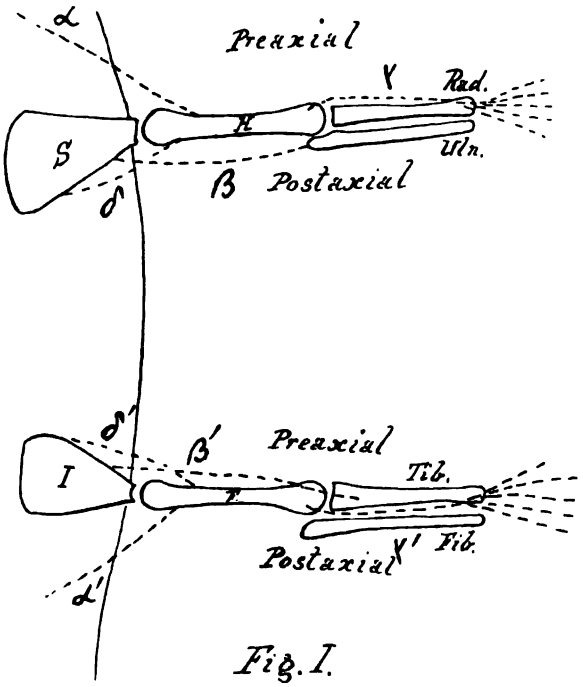


Fig. I.

To show the "looking-glass" symmetry of the muscles of the fore and hind limb from the dorsal aspect.

α, trapezio-deltoid; α', gluteus maximus; β, triceps (long head); β', rectus femoris; γ, extensors of wrist and hand; γ', extensors of ankle and foot; δ, teres major and subscapularis: δ', ilio-psoas.

insertion into the tibia, forming a ligamentum patellæ, and this is due to the great dorso-ventral bulk of the distal end of the femur, as well as to the fact that no apophysis grows up from the tibia toward it. This record of the patella is one of a sesamoid structure pure and simple.

In contrasting the knee with the elbow of an amphibian or lizard, the same bending in a ventral direction is seen; at first slight, though, in higher forms, becoming more marked and accompanied by the same stretching of the dorsal musculature round the distal end of the humerus; but,

In the upper jaw there are *three* separate and distinct downgrowths of the epithelium covering the surface, one of which is shown in fig. 14 and

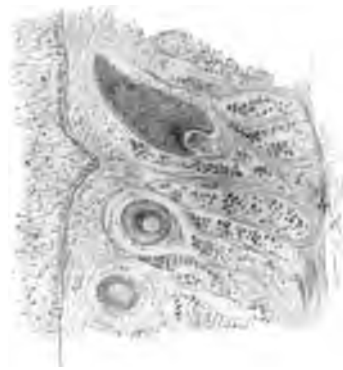


FIG. 11.—The same vestiges more highly magnified.

indicated by the letter *m*. It may very justly be considered that these do not afford sufficient justification for regarding them as tooth-vestiges. They



FIG. 12.—A similar section still more posterior (nearing the hinder margin of hard palate), showing more tooth-vestiges, the lowest one containing a small calcified (?) peg.



FIG. 13.—The lowest vestige highly magnified.

are, however, about as definite and well-marked as the vestiges described by Röse, and which I have shown to be more distinct in this specimen, a fact

observed that there is a posterior calcaneal process of the cuboid, which undershoots the calcaneum, and so supports its front border." Quain says: "The lower internal corner projects backwards as a conical process beneath the anterior extremity of that bone" *i.e.* os calcis.

Of these descriptions, Macalister's is the most graphic. The process "undershoots" the os calcis, supporting it in a bracket-like way—in fact, in a very similar manner to that in which the plantar point, on the navicular, supports the head of the astragalus.



FIG. 1.



FIG. 2.



FIG. 3.

Fig. 1 shows the position of the calcaneal process in the chimpanzee. Fig. 2 shows an approximation of the calcaneal process in man to its position in the chimpanzee. Fig. 3, absence of the calcaneal process in man.

It is well developed in nearly all cases, and either nipple-like or spur-like in shape. It is sometimes very small, and occasionally absent (6 specimens). Amongst the Simiidæ it is present in the chimpanzee and orang, but it is a rounded eminence situated near the middle of the margo plantaris posterior (fig. 1).

The shape of the whole facies articularis posterior, in these animals, presents an interesting contrast to the condition occurring in man. The whole surface dovetails with that of the os calcis, the cuboidal process being received into a well-marked depression. By this arrangement the os calcis and cuboid mutually support each other, much more than is the case in man. The outer portion of the longitudinal arch of the foot, in

these anthropoids, is supported, therefore, by the interlocking articular surfaces of the os calcis and cuboid.

Facies Articularis Anterior.

Outline of the Surface.—The surface in most cases (370—188 right, 182 left) has the shape of a blunt wedge, the truncated apex of which is directed outwards and backwards.

In 82 specimens it is somewhat quadrangular, with rounded angles. In 18 it approached the oval.

The Shape of the Articular Facets.—In some cases the whole surface is concave from above downwards (dorsal to plantar surface). In most of these there is no, or only a slight, ridge separating the two facets for metatarsals 4 and 5. In some the concavity is confined to the surface



FIG. 4.



FIG. 5.

Fig. 4, chimpanzee, showing concavity for 4th, shelving of surface for 5th metatarsal, and ridge between the two facets. Fig. 5, man, showing the same arrangement.

for articulation with the 4th metatarsal. In one the concavity of facies articularis anterior is very irregular, and extends on to the facies plantaris. A well-marked ridge may separate the two articulations. It is not uncommon to get a shelving of the facet for the 5th metatarsal, outwards and backwards. When these three characteristics are combined—*i.e.* a concave surface for the 4th, a shelving of the surface for the 5th, and a well-marked ridge separating the two facets — we have the anthropoid type of articulation in this situation (figs. 4 and 5). These conditions are all probably correlated with greater freedom of movement of the 4th and 5th metatarsal bones, which is, in turn, dependent on the fact that the feet of the ancient Egyptians were not compressed artificially.

The surface is flat or convex in 114 specimens; more or less concave at some part in 339. There is a ridge at the junction of the two facets for metatarsalia 4 and 5 in 144 (61 right, 83 left) specimens. There is a slight tubercle at the junction of these facets, at the margo plantaris anterior only, in 112 specimens (54 right, 58 left), at the margo dorsalis anterior

in 55 specimens (34 right, 21 left), at both margins in 103 specimens (55 right, 48 left).

Another point to which Pfitzner has called attention is in connection with the facet for the 5th metatarsal bone. He has pointed out that this surface may be subdivided by a very slight ridge into two; the outermost of these is for the tuberosity of the 5th metatarsal bone, and it encroaches



FIG. 6.



FIG. 7.



FIG. 8.



FIG. 9.



FIG. 10.

These figures show the chief facet for external cuneiform. Fig. 6, almost equilateral triangle, or cupid's heart shape. Fig. 7, isosceles triangle. Fig. 8, kidney shape. Fig. 9, approached the oval. Fig. 10, oval.

to a slight extent upon the facies lateralis. I found this arrangement well marked in only 5 (3 right, 2 left) specimens, out of 422 examined (figs. 18 and 19). In another specimen there was a well-marked facet on the facies lateralis, but there was no ridge separating it from the facies articularis anterior. It will be seen, therefore, that this subdivision is present only in a small proportion of cases. This is to be expected in a non-boot-wearing people. On the other hand, when the feet are compressed artificially, there would be a tendency for the tuberosity to be pressed against the cuboid.

Facies Medialis.

Direction and Shape.—This surface looks upwards as well as inwards. It is quadrilateral in outline, and offers for our notice (*a*) a facet or facets for articulation with the external cuneiform; (*b*) a frequent facet for the navicular bone; (*c*) an occasional facet for the astragalus; (*d*) a rough area for the attachment of ligaments.

(*a*) Shape of the articular facet for external cuneiform: rounded or "oval" (Cunningham); oval (Morris). In most cases this facet is triangular. To be more exact, in 106 (48·58) cases it is an almost equilateral triangle. In 22 (14·8) cases it is an isosceles triangle with the base at the facies dorsalis; in 76 (44·32) it is an isosceles triangle with its base at the navicular facet. In 31 (12·19) it has the outline



FIG. 11.



FIG. 12.



FIG. 13.

Additional facet near anterior extremity for external cuneiform. Fig. 11, orang, second facet near anterior end for external cuneiform. Fig. 12, man, shows similar facet to the above, which is occasionally present. Fig. 13, man, shows the two facets for external cuneiform continuous.

of a cupid's heart. In 28 (18·10) cases it is distinctly kidney-shaped or crescent-shaped. In 50 (25·25) it approached the oval. It is a complete oval in 17 (7·10). It is a half-oval in two specimens, both left. It is four-sided in 71 (30·41). It is pentagonal or mitre-shaped in 3 (2·1).

The additional occasional facet for the external cuneiform. An interesting difference between the human and the simian foot is the projection of this surface forwards and inwards, in the former, near the facies articularis anterior, which may encroach slightly on this projection. In the simian foot there is a second small facet for the external cuneiform (see fig. 11) on the site of this projection in man, and near the dorsal surface of the bone. There are therefore two facets on the surface, in these animals, for the external cuneiform, separated by a deep groove. The presence of this second facet in the simian foot is possibly due to the

manner in which the animal walks, *i.e.* the cuboid in these animals supporting the navicular and cuneiforms.

This small second facet occurs in 20 (11 right, 9 left) specimens of the present series, or about 4 per cent. of those examined with reference to this point. In some cases it is a quadrilateral facet with the posterior angles rounded. Occasionally the two cuneiform facets are continuous (fig. 13).

(*b*) A frequent facet for the navicular. There was a facet for the navicular in 215 specimens. In 121 cases the shape of this facet is four-sided, and in most of them it has the posterior angles rounded off. In some of the above it is almost square, in others rhomboidal, occasionally oblong; in 54 it is triangular or wedge-shaped, with the base



FIG. 14.



FIG. 15.

Show the shape of the navicular facets. Fig. 14, quadrilateral. Fig. 15, triangular.

of the wedge directed anteriorly. In 32 it is semilunar or half-oval; in 8, pentagonal or mitre-shaped. Frequently the navicular facet extends to the facies articularis posterior; in many cases, however, there is a rough depression between them.

(*c*) In a few specimens there is a small facet for the astragalus situated near the facies articularis posterior, and upon the facies medialis of the calcaneal process. This was present in 3 specimens out of 537 examined. In 2 cases the facet was semilunar, in the other almost oval, in outline.

(*d*) The rough area for the attachment of ligaments. With the exception of the above facets, the whole of the remaining portion is rough for the attachment of ligaments. There is a depression between the cuneiform facet and the facies plantaris in 458 specimens. In 194 of these there is a small tubercle immediately behind the depression.

The extent of the rough area behind the cuneiform facet will of course depend upon the absence or presence of a navicular articulation.

Facies Lateralis.

This surface is the least extensive of all. It is occupied chiefly by the commencement of the groove for the peroneus longus tendon, and by a portion of the peroneal sesamoid facet. Since both of these are situated chiefly on the next surface, they will be considered with it.



FIG. 16.



FIG. 17.



FIG. 18.



FIG. 19.

Figs. 16 and 17, astragalar facets. Figs. 18 and 19, facets for the tuberosity of the 5th metatarsal bone.

Attention has already been drawn to the fact that the tuberosity of the 5th metatarsal bone may articulate with this surface (figs. 18 and 19).

Facies Plantaris.

This surface offers for our notice (*a*) the groove for the peroneus longus tendon; (*b*) the ridge bounding the groove posteriorly; (*c*) the facet for the sesamoid bone or cartilage in the tendon; (*d*) the calcaneal tubercle projecting from the posterior and inner corner of the surface; (*e*) a triangular area posterior to the ridge, between it and the facies posterior.

(*a*) The groove for the peroneus longus is well developed (deep) in 80 (46·34) specimens. It is moderately well developed (fairly deep) in 182 (93·89) specimens. It is slightly developed in 197 (90·107) specimens; almost absent in 32 (12·20), totally absent in 12 (7·5).

(*b*) The ridge bounding the peroneal groove. There is as a rule, of course, a direct relationship between the development of the ridge and the depth of the groove: thus, in most cases, as one would expect, a deep groove is bounded posteriorly by a well-marked ridge. In many cases, however, the ridge is well developed when the groove is quite shallow. In some specimens the ridge is narrow and fairly sharp, in others it is rounded. The most interesting point in connection with it is the presence of the facet for the sesamoid element in the tendon of the peroneus longus.

(*c*) The sesamoid facet. This is situated chiefly on the facies plantaris, though it may encroach on the facies lateralis. Sometimes it is situated in the peroneal groove itself rather than on the ridge. It is generally convex or flattened, occasionally concave. It is oval or nearly oval in outline in most cases, but in some of these it has a process extending along the peroneal ridge forwards and inwards; this gives the whole facet a bottle-shaped appearance.

A process, too, generally quadrilateral in outline, may extend into the peroneal groove. This gives the whole facet a somewhat mushroom-like appearance.

Both the above processes may be present.

In other specimens the facet is half-oval, triangular, wedge-shaped, or rhomboidal. Sometimes it is supported by a small bony process, which juts out posteriorly and plantarwards and supports the calcaneal articulation on its outer side.

The proximity of the peroneal facet to the calcaneal articulation. In many cases the calcaneal facet extends right up to the calcaneal articulation; in others there may be a grooved interval between the two. Of 286 specimens examined with reference to this proximity, in 123 (66 right 57 left) the peroneal facet reached the calcaneal. In 163 there was an interval between the two, usually narrow and grooved, occasionally wide and shallow. The proximity of the two facets will be referred to again under peroneal sesamoid.

(*d*) The tubercle supporting the calcaneal process or spine. This was present in some form in most cases. It was well developed in 129 (68·61) specimens. In most of these the calcaneal process was well developed also. In some, however, the spine is well developed when the tubercle is small. It is interesting to notice that both the calcaneal spine and the

supporting tubercle are absent in the Simiidæ. In these animals, in place of the spine is a rounded eminence, confined to the facies posterior and received into a depression in the os calcis. In none of the specimens was there any indication of the separate existence of this tubercle.



FIG. 20.



FIG. 21.



FIG. 22.



FIG. 23.

Show facets for os peroneum. Fig. 20, oval in outline. Fig. 21, nearly oval. Fig. 22, flask-shaped. Fig. 23, process extending from facet into the peroneal groove.

(*e*) The area behind the peroneal ridge, between it and the facies posterior, is generally smooth and perforated by foramina for nutrient vessels. In most bones it is depressed, in some markedly so, there being in these a deep concavity between a well-marked peroneal ridge and a prominent calcaneal tubercle. This is for the short plantar ligament. There is a well-marked depression in this position also in the Simiidæ, though in these animals the calcaneal tubercle is absent.

Facies Dorsalis.

This surface is four-sided. It is prolonged upwards and inwards at the superior internal angle, where it not infrequently has a small tubercle for the attachment of the internal calcaneo cuboid ligament.

This surface is often somewhat smooth, and is perforated by foramina for nutrient vessels.

There is an eminence or ridge with a groove behind it near the outer part of the margo dorsalis posterior in many cases.

There is an eminence or oblique ridge running forwards and inwards just in front of the position of the last-mentioned ridge in others.

There is a slight groove with sometimes a ridge behind it near the margo dorsalis anterior in many specimens. Sometimes the bone is concave about the centre.

The Os Cuboides in the Anthropoid Apes.

ANTHROPOIDEA. SIMIIDÆ.

ANTHROPOPITHECUS TROGLODYTES.

Facies Posterior.

This surface is somewhat wedge-shaped, with the base of the wedge directed upwards and outwards. It is concavo-convex from above downwards (in its long diameter). It possesses a small calcaneal process which, however, is not spine-like, but rounded, and fits into a depression on the facies articularis anterior of the os calcis. This eminence, together with a concavity immediately below it, makes the whole facies posterior dovetail with the facies anterior of the os calcis. This is probably correlated with the greater inversion of the foot in these animals, and as a result of this interlocking the posterior surface of the cuboid not only articulates with, but is supported by, the os calcis; in man, on the other hand, it is rather the cuboid which supports the os calcis by means of its calcaneal process.

The above process seems to act as a pivot on which the cuboid turns, when the lateral movements are performed at the transverse tarsal joint.

Facies Anterior.

The whole surface is wedge-shaped, with its base directed supero-externally. It is subdivided by a slight ridge or eminence into two articulations for the 4th and 5th metatarsal bones. These are quite different in character.

Articulatio cubo-metatarsi IV.—This is quadrilateral in outline, is

distinctly concave both from above downwards and from side to side. It articulates with the rounded inferior portion (outer portion it would be in human anatomy) of the 4th metatarsal bone. There is a small tubercle on the margo superior close to the superior anterior angle of this surface.

Articulatio cubo-metatarsi V.—This is wedged-shaped, with the base of the wedge at the ridge separating this surface from articulatio cubo-metatarsi IV. There is a slight tubercle, at the dorsal extremity of this ridge, which fits into the interval between the 4th and 5th metatarsals. The surface for the 5th metatarsal bone is flattened or slightly convex, and shelves towards the plantar surface.

The Facies Medialis.

The facies medialis presents two facets—a large posterior one, which is oblong, with the angles rounded off, or somewhat semilunar or wedge-shaped, with its base at the margo posterior. This surface is for articulation with both the navicular and the external cuneiform. The facet for articulation with these two bones is practically one, only a very faint ridge marking the separation. The second facet is very small and somewhat wedge-shaped in outline, with its base directed anteriorly. It is also for articulation with the external cuneiform. There is a rough depressed area between these two facets for the attachment of ligaments.

Facies Lateralis.

From the position of the foot in these animals, it looks downwards rather than outwards. It is marked by the commencement of the groove for the peroneus longus.

Facies Plantaris.

This surface possesses a ridge, with a peroneal groove in front of it, and a rough surface behind it.

The ridge is sharper than in human anatomy, and is not marked by a peroneal facet, though this is present in the fresh state. The peroneal groove is deeper and narrower than in human anatomy. The rough ligamentous surface behind the ridge is somewhat depressed and is marked by one or two large medullary foramina.

Facies Dorsalis.

The surface is quadrilateral in outline. There is no groove near its margo dorsalis posterior.

SIMIA SATYRUS.

Facies Posterior.

This surface is somewhat semilunar or wedge-shaped in outline. It is concavo-convex from above downwards. It has a calcaneal process similar to that in the chimpanzee.

Facies Anterior.

This surface forms a more blunt wedge than in the chimpanzee, and the two facets into which it is divided are usually separated by a more prominent ridge than in that animal. There is a little tubercle in three of the specimens at the plantar end of the ridge, and one at each end in a fourth specimen.

Articulatio cubo-metatarsi IV.—The facet is quadrilateral and concave as in the chimpanzee.

Articulatio cubo-metatarsi V.—This has the shape of a blunt wedge, and shelves considerably towards its apex, so that the surface looks downwards and outwards as well as forwards.

Facies Medialis.

This possesses, in three specimens, two wedge-shaped facets—a larger, posterior, with its base directed backwards, and a smaller, anterior, with its base directed forwards. The posterior facet articulates with both the navicular and external cuneiform, the anterior with the external cuneiform. Between the two facets is a rough surface for interosseous ligaments.

Facies Lateralis.

This is marked by the commencement of the groove for the peroneous longus tendon.

Facies Plantaris.

This surface presents the well-marked ridge bounding the peroneal groove posteriorly.

The ridge, however, is not marked by a facet for a peroneal sesamoid bone, and is sharper than in human anatomy. The peroneal groove is deeper than the corresponding groove in man. There is the rough surface behind the ridge, which is marked by medullary foramina as in the chimpanzee.

Facies Dorsalis.

There is a very slight narrow groove near the margo dorsalis posterior in two of the specimens.

HYLOBATES.

Facies Posterior.

Surface somewhat wedge-shaped, much flatter than in chimpanzee and orang. The cuboidal process is very small, and this bone and the os calcis do not dovetail as in the other anthropoid specimens.

Facies Anterior.

Articulatio cubo-metatarsi IV.—A small quadrilateral concave facet for the rounded proximal extremity of the 4th metatarsal bone.

Note.—This is the only one of the metatarsal bones which possesses a rounded extremity at its base. *Articulatio cubo-metatarsi V.* is wedge-shaped, and shelves backwards towards the inferior aspect of the bone.

Facies Lateralis.

Groove for peroneus longus.

Facies Plantaris.

Groove for peroneus longus with ridge behind it. No facet on ridge for sesamoid bone.

Facies Dorsalis.

Nothing of interest in connection with this surface.

The Peroneum or Peroneal Sesamoid

The account of this structure is chiefly of a comparative rather than of a descriptive nature. The description of this element has been so exhaustively dealt with by Professor Pfitzner that little remains to be added. He found it present in 8 to 9 per cent. only.

Position.—In most cases the facet on the cuboid for the peroneum, as stated earlier, is situated chiefly on the facies plantaris. Its varieties of shape have been considered in the description of the cuboid. With reference to the position of the facet, Pfitzner states: "Only in extreme cases does the peroneum extend up to the calcaneo-cuboid articulation or even beyond. Usually it remains far removed from it. If, then, direct relationships have existed formerly between calcaneus and peroneum, these have, in any case, first retrogressed." In the series of Egyptian cuboids which I examined with reference to this point, in 43 per cent. the peroneal facet reached the calcaneal; in the remainder there was an interval between the two facets.

The proximity of the peroneal facet to the calcaneo-cuboid articulation, in man, is interesting, since these two facets are nearer each other in the lower primates than in man. Indeed, in the specimens of *Cynocephalus* which I examined, the peroneum articulated not only with the cuboid, but to a slight extent with the anterior and outer extremity of the os calcis.

The Surfaces of Contact.—According to Pfitzner, the contiguous surfaces of the peroneum and cuboid are, in man, not truly articular. He states that they do not possess two hyaline clad articular surfaces in direct contact, but that, even when cartilage is present, it is always covered by a layer of connective tissue. This condition he regards as a sign of retrogression. In the lower apes, according to Gillette and Pfitzner, the bones articulate by means of a hyaline cartilaginous surface. In the specimens which I examined microscopically, I found much more fibrous tissue in man than in the lower primates.

The Peroneum in Other Primates.

SIMIIDÆ.

GORILLA. ANTHROPOPITHECUS TROGLODYTES. SIMIA SATYRUS.

There is merely a slight thickening in the peroneus longus tendon, no peroneum. There is a cartilage-covered surface on the cuboid, for articulation with the above thickening in peroneus longus. This articular surface is confined to the cuboid; it is not found in the dry specimens of orang and chimpanzee which I examined.

HYLOBATES.

There is a sesamoid, which is small and bony, in the tendon of the peroneus longus. The facet on the cuboid is confined to that bone, and the peroneum does not articulate with the os calcis.

CERCOPITHECIDÆ.

CYNOCEPHALUS.

Peroneum is cartilaginous. The cartilage articulates, to a slight extent, with the fore part of the os calcis.

CERCOPITHECUS FULIGINOSUS.

Peroneum of fair size, cartilaginous, somewhat oval. The facet on the cuboid is cartilage-covered and confined to the cuboid.

CERCOPITHECUS CALLITRICHUS.

The peroneum is well developed, ossified, and oval in shape. The facet on the cuboid is oval in shape, cartilage-covered, and confined to the cuboid. The peroneum is not in the centre of the tendon, for it has more fibrous structure superficial to it than on its articular surface.

In three other specimens of *Cercopithecus* the peroneum was somewhat oval in shape; in two, cartilaginous; in one, osseous.

In none of these did the peroneum articulate with the os calcis, though in all, the peroneal facet on the cuboid extended as far back as the calcaneo-cuboid articulation.

MACACUS NEMESTRINUS.

In both of these specimens examined, peroneum was fairly well developed, osseous, and oval in shape. The cuboid facet is oval and cartilage-covered. The peroneum does not articulate with the os calcis, though in one of them the peroneal facet is close to calcaneo-cuboid articulation.

MACACUS RHESUS.

Peroneum is very small, chiefly cartilaginous; osseous towards the centre to a slight extent.

SEMNOPITHECUS.

In this specimen peroneum is fairly well developed, oval in shape, and bony. Facet on the cuboid is oval, cartilage-covered, and confined to the cuboid.

CEBIDÆ.

In *Cebus* the peroneum is small, oval, and cartilaginous. Facet is confined to the cuboid.

In *Lagothrix* slight thickening in the peroneus tendon: cuboid facet is near the calcaneo-cuboid articulation.

In *Ateles* merely a thickening in peroneus: facet on cuboid is close to calcaneo cuboid articulation.

In *Chrysothrix* the peroneum is small and cartilaginous. The facet on the cuboid is confined to that bone.

HAPALIDÆ.

HAPALE.

Two specimens examined. In both these specimens the sesamoid bones were absent; no trace, cartilaginous or otherwise.

LEMUROIDÆ.

LEMURIDÆ.

Merely thickening in peroneus. Facet on cuboid is cartilage-covered and confined to the cuboid, though it extends as far backwards as calcaneo-cuboid articulation.

Summary of the most Interesting Observations.

(1) The shape of the facies articularis posterior in the Simiidæ, and the dovetailing of the cuboid and calcaneum in these animals.

(2) On the facies articularis anterior, a combination in some cases of the following anthropoid characteristics:—

(*a*) A concave surface for the 4th metatarsal.

(*b*) A shelving of the surface for the 5th metatarsal downwards and outwards.

(*c*) A well-marked ridge separating the two articulations.

(3) The frequent presence of the articulatio cubo-navicularis.

(4) An occasional facet for the astragalus.

(5) A second facet for the external cuneiform situated at the anterior end of the facies medialis.

(6) The constant presence of the last-mentioned facet in the Simiidæ.

(7) An occasional facet on the facies lateralis for articulation with the tuberosity of the 5th metatarsal bone.

(8) The degree of proximity of the peroneal facet to the calcaneo-cuboid articulation, in man and in other primates.

(9) The articulation, in the Cynocephali, of the peroneum with the anterior and outer extremity of the os calcis, as well as with the cuboid.

(10) The more constant occurrence of the peroneum amongst the lower than amongst the higher primates, especially in the Old World monkeys below the Simiidæ.

(11) The great variability in shape of the facet for the os peroneum.

(12) The large amount of fibrous tissue in the cartilage of the peroneal facet in the human subject.

(13) The frequent presence, in man, of a small slip from the peroneal sesamoid to the base of the 5th metatarsal bone.

(14) The fact that in none of the specimens was there the slightest evidence of a cuboides bipartitum.

(15) The fact that in none of the specimens was there the slightest evidence of the separate existence of Pfitzner's so-called cuboides secundarium.

In conclusion, comparing this bone with the navicular, the great similarity in general outline of the specimens of cuboid to each other offers a strong contrast to the great variability in the shape of the navicular. This is partly due to mechanical conditions on the two sides of the foot, and partly to the different times at which the bones ossify.

Though the two bones are markedly alike in each possessing a so-called sesamoid element in its neighbourhood, the behaviour of these elements is different on the two sides. On the inner aspect of the foot, the tibial sesamoid (tibiale externum) may either articulate or fuse with the navicular, in the latter case, prolonging the tuberosity proximally. On the outer side, though the peroneal sesamoid (os peroneum) articulates and does not fuse with the cuboid, the large amount of fibrous tissue in the joint probably indicates that the articulation is regressing in man; in other words, that the condition is a step on the way either to disappearance or to fusion of the peroneal element with the cuboid. The os hamuli proprium in the carpus has possibly passed through the same transition. The explanation of these differences, both in the hand and foot, may depend upon the fact that all these elements are probably the remains of additional digits, which may apparently assume sesamoid functions only, as the os pisiforme, or os peroneum, fuse entirely like the os hamuli proprium, or, as in the case of the tibiale externum, play either of these parts.

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SYNOVIAL MEMBRANES, WITH SPECIAL REFERENCE TO THOSE RELATED TO THE TENDONS OF THE FOOT AND ANKLE.

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(Read at Edinburgh, July 27, 1907.)

THE NATURE OF SYNOVIAL MEMBRANES.

SYNOVIAL membranes, like serous membranes, are connective-tissue structures placed between two movable tissues so as to diminish friction. They are composed essentially of areolar tissue, containing numerous vessels and nerves. All synovial membranes bound closed cavities. The surface towards the cavity secretes synovia.

Synovia is a transparent, yellowish-white or slightly red fluid, viscid like the white of egg, having an alkaline reaction and slightly saline taste. It is a rich body fluid in which is a mucin-like substance; to the latter constituent it owes its viscosity.

The synovial membranes of the body admit of subdivision into three classes: articular, bursal, and vaginal. This paper is concerned with the last two of these.

BURSÆ are found interposed between surfaces which move upon one another, as where there is gliding of a tendon or of the integument over a projecting bony surface. They admit of subdivision into two kinds—bursæ mucosæ and bursæ synoviæ. The bursæ mucosæ are large simple or irregular cavities in the subcutaneous areolar tissue; they enclose a clear fluid. They are classed as synovial membranes in *Gray's Anatomy*,[1] but are not true synovial structures; they have, however, a similar function. Some are developed during life; others, such as the malleolar bursæ, are present at birth. The bursæ synoviæ are found (*a*) between two tendons, (*b*) between tendons and bony surfaces, and (*c*) between tendons and fascial bands. They are true synovial sacs, and may communicate with joints.

VAGINAL SYNOVIAL MEMBRANES serve to facilitate the gliding of tendons in the osseo-fibrous canals through which the tendons pass. Such membranes occur only in relation to tendons. The simplest conception of their

[1] Chapter on the Articulations, p. 347, in 1905 edition.

arrangement is that each is an elongated synovial sac into which a tendon is completely invaginated, a meso-tendon being thus formed connecting the visceral or tendinous layer to the parietal or osseo-fibrous layer. This invagination is not their mode of origin; we refer to this point below.[1] The tendinous and osseo-fibrous layers are always continuous at the ends of a sheath. They are often also continuous either along the whole length of the sheath or at various points in it, through the medium of meso-tendons. Now, a tendon with its attached "tendinous" layer of membrane, on contraction of its muscle, takes up a new position relative to the walls of its osseo-fibrous canal and to the parietal layer of membrane which is attached to the latter. Hence a special arrangement is necessary to prevent rupture of the synovial membrane at the point where the tendinous and parietal layers become continuous at the end of a sheath.

The relation of synovial membrane to the tendon of the tibialis anticus at its upper limit is typical of the mechanism which nature employs to obviate rupture. Hence we will describe it here.[2]

The muscle becomes tendinous on its superficial aspect, and its tendon lies in a special osseo-fibrous canal (fig. 1). The parietal layer of synovial membrane attached to the anterior wall of the canal passes upwards, and reaches a point close to where the muscular fibres become tendinous. So far the secreting surface is directed posteriorly. Here, however (*a*, fig. 1) the parietal layer ceases to be attached to the wall of the canal. It is reflected for a distance of nearly 1 cm. in a downward direction. In this situation it is not attached to tendon or canal wall; its secreting surface looks forward. It is now again reflected, this time in an upward direction (*b*, fig. 1); it is still unattached, but its secreting surface now looks backwards. Having ascended for about ·5 cm., it is once more folded back so that its secreting surface now looks forwards; this time it is attached to the anterior surface of the tendon forming the "tendinous" layer. In longitudinal section this arrangement is sigma (Σ) shaped. If the sheath be injected with coloured gelatin and the injection be hardened in formalin, one can, by careful dissection, raise the anterior or osseo-fibrous cul-de-sac from the posterior or tendinous cul-de-sac. These cul-de-sacs lie on the superficial aspect of the tendon. The line along which the tendinous layer of synovial membrane is reflected to form the parietal layer in the upper part of the sheath is oblique, passing from above downwards and backwards (*cf.* rectum and peritoneum). Lower down, the sheath comes to completely envelop the tendon, though the latter does not actually lie inside the cavity of the sheath.

[1] Page 417.

[2] See also Poirier, vol. ii., ch. iv., p. 178.

As regards the development of synovial membranes, we would quote passages from Poirier's excellent description.[1] "It is evident that synovial membranes are intimately related to the movements of their several tendons. One must not, however, believe that intra-uterine muscular contractions create synovial membranes. This was Velpeau's opinion. He thought the tendons were embedded in an amorphous substance, which by constant friction they pressed out and flattened into lamellæ; in the latter, this

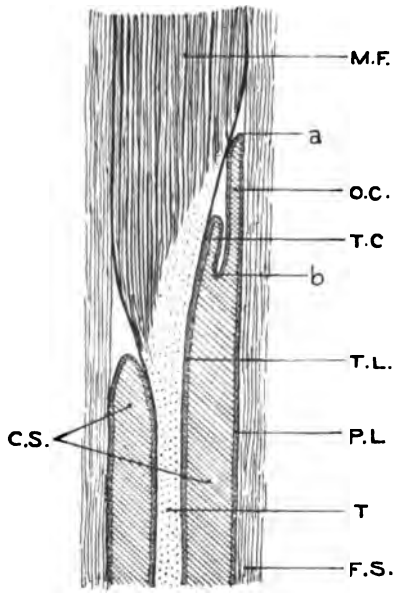


FIG 1.—Diagrammatic longitudinal section through the end of a typical synovial tendon sheath.

T., tendon; M.F., muscle fibre; F.S., fibrous sheath; C.S., synovial cavity; P.L., parietal layer of synovial membrane; T.L., tendinous layer; O.C., osseo-fibrous cul-de-sac; T.C., tendinous cul-de-sac; *a*, *b*, see text, p. 416.

friction eventually produced a synovial cavity. This theory, based purely on dissection, is incorrect. Retterer and Chemin have shown, by histological methods, that the synovial structures are formed in the fœtus at a period when the muscles are incapable of producing enough movement to create such structures. We see then that, phylogenetically, constant friction has demanded the development of synovial structures. *They are now normal organs transmitted by heredity.* The movements, however, play

[1] Poirier, vol. ii., ch. iii., p. 77.

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[1] Page 417.

[2] See also Poirier, vol. ii., ch. iv., p.

SIMIA SATYRUS.

Facies Posterior.

This surface is somewhat semilunar or wedge-shaped in outline. It is concavo-convex from above downwards. It has a calcaneal process similar to that in the chimpanzee.

Facies Anterior.

This surface forms a more blunt wedge than in the chimpanzee, and the two facets into which it is divided are usually separated by a more prominent ridge than in that animal. There is a little tubercle in three of the specimens at the plantar end of the ridge, and one at each end in a fourth specimen.

Articulatio cubo-metatarsi IV.—The facet is quadrilateral and concave as in the chimpanzee.

Articulatio cubo-metatarsi V.—This has the shape of a blunt wedge, and shelves considerably towards its apex, so that the surface looks downwards and outwards as well as forwards.

Facies Medialis.

This possesses, in three specimens, two wedge-shaped facets—a larger, posterior, with its base directed backwards, and a smaller, anterior, with its base directed forwards. The posterior facet articulates with both the navicular and external cuneiform, the anterior with the external cuneiform. Between the two facets is a rough surface for interosseous ligaments.

Facies Lateralis.

This is marked by the commencement of the groove for the peroneous longus tendon.

Facies Plantaris.

This surface presents the well-marked ridge bounding the peroneal groove posteriorly.

The ridge, however, is not marked by a facet for a peroneal sesamoid bone, and is sharper than in human anatomy. The peroneal groove is deeper than the corresponding groove in man. There is the rough surface behind the ridge, which is marked by medullary foramina as in the chimpanzee.

Facies Dorsalis.

There is a very slight narrow groove near the margo dorsalis posterior in two of the specimens.

an important part in the growth and modelling of the sheaths. Histologically, the tendon is originally embedded in a homogeneous tissue in which the fibrous canals are seen as denser tracts. The embedding tissue takes on a mucous character. It then entirely disappears and gives place to the first synovia. The mode of growth of once formed synovial structures and the formation of adventitious bursæ are similar. Velpeau's theory is one of intercellular formation; Retterer's, on the contrary, is one of transformation of protoplasm, *i.e.* of intra-protoplasmic origin."

Synovial membranes may be compared with serous membranes; like the latter, they bound closed cavities lubricated by fluid. They are not connected with the lymphatic system, nor is lymph the fluid which moistens them, but serous cavities are connected to the lymphatic system through lymph stomata. In synovial membranes we only find isolated patches of epithelial cells; in serous membranes there is a continuous pavement epithelium. On synovial membranes, in contrast to serous ones, we meet with long villus-like projections; they are often covered by small rounded cells, and probably serve to increase the surface for the secretion of synovia. Synovial sacs resemble serous sacs in their relation to the organ enveloped. The latter is invaginated into the sac in each case. When complete invagination occurs a "meso-membrane" is formed, *e.g.* a meso-tendon in the case of the tibialis anticus sheath, and a mesentery in the case of the small intestine. Between the two layers of any meso-membrane, vessels and nerves pass to the organ enveloped. Cases where invagination is not complete are common to both kinds of membrane, *e.g.* the bursæ of the lumbricals and the tunica vaginalis of the testicle. Here no meso-structures are found. There is an interesting similarity between the adaptation of synovial and serous membranes to the movements of the organ enveloped. A special arrangement of synovial membrane has been described at the upper end of the tibialis anticus sheath. A similar arrangement on a larger scale is found in the relation of the peritoneum to the anterior abdominal wall. Here there is a part of the peritoneum, at the point of reflection, unattached to either bladder or abdominal wall. This arrangement allows the free distension of the bladder with urine. Synovial sacs differ from serous sacs in their mode of origin. The former are formed by absorption and transformation of primitive tissue. The latter have a schizogenetic origin.

In writing the following description we have tried to describe the most usual disposition of the synovial structures. It must be remembered, however, that variations will occur under conditions such as excessive development of tendon or fascia, absence of muscles (*e.g.* peroneus tertius), and the presence of extra tendinous slips.

The Synovial Membranes in Relation to the Tendon of Tibialis Anticus. (Fig. 2.)

The tibialis anticus muscle becomes tendinous on its superficial aspect some 4 inches above the ankle joint. It passes under all the divisions of the anterior annular ligament, having a fibrous compartment to itself under each division. It is inserted into the inner aspect of the internal cuneiform and the base of the first metatarsal.

Its synovial sheath (*a*, fig. 2) extends from a point just above the astragalo-scaphoid joint for a distance of some 8 or 10 cms. in an upward direction. The highest point of the sheath is given by various authors in regard to the anterior annular ligament, and in each case differs. Thus Testut [1] says 3 to 4 cms. above the ligament, while Toldt's *Atlas* [2] shows it not appearing above the ligament at all. As the ligament in question is more or less arbitrarily defined, it is better not to take it as a landmark. Bouchard [3] says the upper limit is only just above that of the extensor longus digitorum sheath, but he gives the length of the tibialis anticus sheath as only 4·5 cms. The Σ-shaped arrangement of the membrane at the upper limit of the sheath has been fully described above.[4] There is a complete meso-tendon throughout the length of the sheath. There are two bursæ at the insertion of this tendon (*h*, fig. 2). These bursæ bear a special relationship to the tendinous fibres and to the bones. The fibres of the tendon split quite close to the insertion into two layers—deep and superficial. The former layer, which is the smaller, is inserted into the lateral aspect of the internal cuneiform. The latter layer is inserted into the dorsal and lateral aspects of the base of the first metatarsal. The layers are continuous plantarwards, but are distinct dorsally. Between them in this position is the cuneo-metatarsal joint, and over this (still between the layers) lies a bursa. There is a facet for this bursa on most internal cuneiform bones. In all the specimens examined this bursa was continuous with the synovial cavity of the joint, and we believe that it is a protrusion of the joint. Bouchard mentions this bursa and takes this view of it.[5] He further states that the sheath, bursa, and joint may all communicate. It is difficult to see how this can occur, as the deep layer of fibres of insertion must always intervene.

There is another bursa under the deep layer of fibres, between them and the groove on the cuneiform. This bursa, but not the former, is

[1] Testut, vol. i., book iii., ch. vii., article iii., p. 969.
[2] Toldt's *Atlas*, p. 356, fig. 597.
[3] Bouchard's Essay (see Bibliography).
[4] *Vide* p. 416.
[5] Bouchard (see Bibliography).

described by Poirier.[1] We have never observed this bursa and the sheath in communication, but Poirier says he did so once. In this case the sheath extended down to the insertion of the muscle.

Poirier states that Cannieu twice observed the communication of this sheath with that of extensor longus hallucis at the level of the superior cul-de-sacs. The tibialis sheath must have been short or the extensor longus hallucis sheath must have been long in these cases.

There is a strong band of fascia stretching from the internal cuneiform and base of metatarsal I to the base of metatarsal II (*k*, fig. 2). We have twice observed a bursa between this band and the superficial surface of the tendon. In these cases the fascial band was very strong.

The Synovial Membranes in Relation to the Tendon of the Extensor Longus Hallucis. (Fig. 2.)

The upper limit of the synovial sheath of the extensor longus hallucis is the point where the line joining the prominences of the external and internal malleoli meets the tendon. This point is 2 inches above the astragalo-scaphoid articulation and about 2 inches below the upper limit of the synovial sheath of the tibialis anticus. It lies slightly above the upper band of the lower part of the anterior annular ligament.

In two cases which we observed the upper limit was nearly 2 inches higher, being in these cases at the same level as the upper limit of the tibialis anticus sheath.

The main sheath ends just above the cuneo-metatarsal joint of the big toe, and just above the fascial band which stretches from the internal cuneiform and the base of metatarsal I to the base of metatarsal II; thus the sheath is about 3 inches long.

At the level of the cuneo-metatarsal joint a bursa intervenes between the tendon and the bones (*i*, fig. 2). In all cases we have examined this bursa was present. Morestin[2] found it very frequently in sixty cases he examined.

It may communicate with the main sheath; when it does so, the sheath is prolonged on to the dorsal surface of metatarsal I. We have seen it so arranged. Bouchard once traced it to the dorsal surface of the first phalanx. At the same level as the bursa just described, but independent of it, is another which is placed on the superficial aspect of the tendon, between the latter and the fascial slip from metatarsal I to metatarsal II. These bursæ may communicate. According to Poirier[3] they do so more often than not

[1] Poirier, vol. ii., ch. iv., p. 300.
[2] Morestin, *Soc. Anat.*, Oct. 1894, p. 715.
[3] Poirier, vol. ii., ch. iv., p. 301.

by an oval opening of variable size. The latter authority in rare cases finds a third very small bursa at the level of the head of metatarsal I, intervening between the tendon of the extensor longus hallucis and the innermost tendon of the extensor brevis digitorum. We cannot find this bursa, but the latter tendon has a sheath, hereafter described. The tendon of the extensor longus hallucis often gives off a slip, about the level of these bursæ, to be inserted separately into the inner side of the base of the first phalanx of the great toe. In a case which we observed, this slip had a distinct sheath along most of its course, the sheath being continuous with the subtendinous bursa.

There is a meso-tendon along the whole length of the main sheath.

Synovial Membranes in Relation to the Tendons of the Extensor Longus Digitorum and Peroneus Tertius. (Fig. 2.)

These tendons have a common sheath about 7·5 cms. long. Superiorly it begins 2 or 3 cms. above the ankle joint, that is, about 1 cm. above the upper limit of the extensor longus hallucis sheath. Normally it does not extend above the lower limit of the upper band of the anterior annular ligament. In two cases, we observed that it extended higher than the superior limit of the band. It passes under the undivided part of the lower band. Here the main tendon splits into four digital tendons; these and the peroneus tertius tendon diverge; the sheath widens proportionately and ends over the scapho-cuneiform articulation.

At the upper end of the sheath there is a very marked Σ-shaped arrangement. In one case we saw both cul-de-sacs 1·5 cms. long. The muscle first becomes tendinous on its inner side and superficially, so we find the sheath reaching its highest point on the inner side of the muscle. The line of reflection of the membrane in the upper and anterior part of the sheath is the oblique line along which the muscular fibres become tendinous. In a well-developed subject the main tendon of the long extensor has divided into two or three slips half way down the sheath. On the outer side of these is the tendon of the peroneus tertius, with muscle fibres still passing to it from the fibula.

A section at this level shows the three tendons completely invaginated into the synovial sac, a single meso-tendon passing to them posteriorly from the fibular side. The sheath ends inferiorly in a large blind sac, which is subdivided into small sac-like prolongations. Each of the digital tendons has a prolongation in relation to it for about ·5 cms. on its superficial aspect. These prolongations are each arranged in the Σ-shaped manner above described. On the peroneus tertius tendon there is no such

arrangement, and indeed one is not necessary, as its range of movement is small.

There is sometimes a bursa between the head of the astragalus and the tendons (*x*, fig. 2); the bursa is a large one, and is generally present when the origin of the extensor brevis digitorum does not extend as high as usual on the anterior annular ligament. In many cases the muscular origin intervening between the bone and the tendons seems to obviate the necessity for a bursa. It may be more correct to say that in some cases muscle tissue gives rise to a bursa. In this connection we may consider the fact, lately applied to surgery by Dr Alphonse Huguier,[1] that new joints are formed between osseous fragments when muscle tissue is interposed. The interior of these joints is lined by secretory endothelium. The above bursa was described by Synnestvedt[2] as the "bursa sinus tarsi" or "bursa mucosa Gruberi." According to Poirier,[3] it generally communicates with the main sheath; in no case have we been able to demonstrate this. We have, however, seen a case in which the bursa communicated with the astragalo-scaphoid joint. Such a communication is mentioned in *Morris' Anatomy*.[4] Synnestvedt states that a bursa has been described as sometimes occurring at the insertion of the peroneus tertius. He does not confirm its occurrence. We have never seen one in this situation.

Bougery's *Atlas*[5] shows three other bursæ in relation to the tendons to the second, third, and fourth toes. Poirier[3] states that these do not occur, but that they are represented by loose areolar tissue. We find, however, that in some cases synovial structures are present in relation to all the tendons of the extensor longus digitorum (*d*, fig. 2). Evidence of these may often be seen by dissection. We have injected them in four well-developed adults. They proved to be true synovial sheaths with definite limits. They were reflected when we reflected the tendons, and they were in intimate relation to the tendons and sheaths of the extensor brevis digitorum hereafter described. In some feet these sheaths are not developed. When present their limits depend on the development of the tendons and deep fascia.

The Synovial Membranes in Relation to the Tendons of the Extensor Brevis Digitorum. (Fig. 2, *e*.)

All four tendons of this muscle when well developed have synovial sheaths. We have not seen these described, but have injected them in two

[1] *The Practitioner*, Feb. 1907, "Orthopœdic Surgery," by A. H. Tubby, M.S., F.R.C.S.
[2] Synnestvedt's Essay, p. 74 and pl. iv. 5, fig. *e*.
[3] Poirier, vol. ii., ch. iv., p. 302.
[4] Morris, p. 1253, edition 1902. Holden is quoted.
[5] Bougery's *Atlas*, vol. ii., pl. 159.

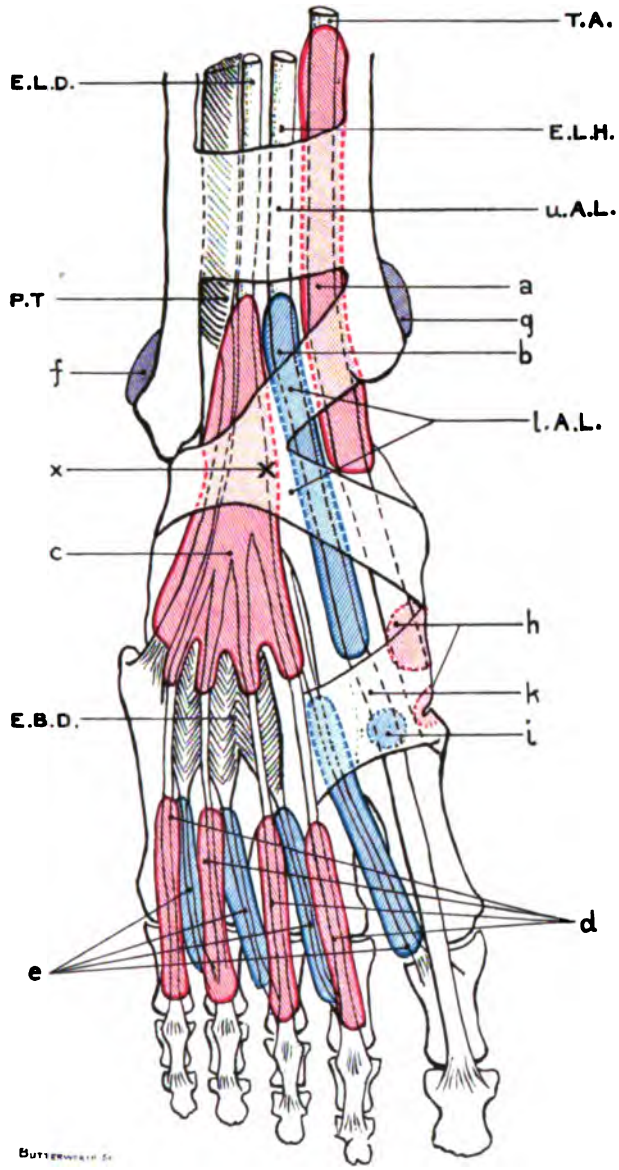


FIG. 2.—Synovial sheaths on anterior aspect of foot.

T.A., tibialis anticus; *a*, its sheath; *h*, its bursæ. E.L.H., extensor longus hallucis; *b*, its sheath; *i*, its bursæ. E.L.D, extensor longus digitorum. P.T., peroneus tertius. *c*, sheath common to E.L.D. and P.T. *d*, digital extensor sheaths of E.L.D. E.B.D., extensor brevis digitorum. *e*, digital extensor sheaths of E.B.D. *x*, position of bursa sinus tarsi. *f* and *g*, malleolar bursæ. *u*.A.L. and *l*.A.L., upper and lower portions of anterior annular ligament. *k*, thickened band of deep fascia.

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feet. The longest sheath is in relation to the innermost tendon. This we have also injected in a boy's foot. It extends from near where the tendon originates to the proximal end of the first phalanx. The sheath envelops the tendon as it passes under the fascial band between metatarsals I and II. In the adult foot it was 5·5 cms. long. The sheaths of the three outer tendons are from 3 to 4 cms. long; they lie just deep to the digital sheaths of the extensor longus digitorum tendons.

Two bursæ are figured by Synnestvedt [1] in relation to the muscle. One is under the innermost tendon at the point where the muscular fibres become tendinous. This one we have seen. The other he figures under the main outer muscle mass just at the point where the tendons originate; this bursa we have not found.

The Synovial Membranes in Relation to the Tendons of the Peroneus Longus and Peroneus Brevis.

These tendons have a complicated arrangement of synovial membranes in relation to them. Behind the external malleolus the tendons have a common sheath, which bifurcates for a short distance above and for a longer distance below. The tendon of the peroneus brevis is inserted into the prominent base of the fifth metatarsal, but that of the peroneus longus winds round to reach the inner side of the sole. In its plantar course it has a distinct sheath, which may or may not communicate with the malleolar sheath.

The common sheath extends for 2·5 to 3·5 cms. above the external malleolus. At this point the peroneus longus, wholly tendinous, lies superficial to the peroneus brevis, which is receiving muscle fibres on its deep aspect. On bifurcation, the sheath extends for 2·5 cms. further on the peroneus longus and for 1·5 cms. further on the peroneus brevis. In this situation there lies between the tendons a partition covered by synovial membrane, ending inferiorly in a free edge concave forwards. On each tendon there is a marked Σ-shaped arrangement superiorly. Each tendon has a meso-tendon. In some subjects this is absent beyond the peroneal tubercle in the case of both tendons.

According to Poirier,[2] the common sheath "effects two important communications with the synovial cavity of the ankle joint, one above and one below the posterior fasciculus of the external lateral ligaments on which it rests." We have not been able to demonstrate these communications.

Inferiorly, the common sheath bifurcates at the peroneal tubercle. One

[1] Synnestvedt's Essay, p. 75, and plate iv., fig. *e*, 9 and 10.
[2] Poirier, vol. ii., ch. iv., 302.

diverticulum envelops the tendon of the peroneus brevis to within 2 cms. of its insertion; that is to say, as far as a point just in front of the calcaneo-cuboid articulation. The other diverticulum accompanies the tendon of the peroneus longus to the region of the groove on the cuboid. On the superficial surface of the tendon it extends for about 1 cm. beyond the peroneal tubercle. On the osseous surface it extends much further—in fact, right into the groove.

The plantar sheath extends from the insertion of the tendon to the region of the groove on the cuboid (P. P. L., fig. 3). It is nearly 4 cms. long. Like the malleolar sheath, it is continued right into the cuboid groove on the osseous surface, but stops short on the superficial aspect of the tendon. Thus the malleolar and plantar sheaths are widely separated on the superficial aspect, but are merely separated by a membrane on the osseous aspect. Through this membrane the sheaths may or may not communicate. Poirier[1] states that the communication exists in 33 per cent. of subjects. He quotes and disputes an authority who says it never exists. Spalteholz[2] states that the communication is rare. Continuity of the sheaths, when it does occur, is always on the deep aspect.

On the posterior wall of the groove on the cuboid there is a facet for the joint between that bone and the sesamoid cartilage (rarely bone) found in the tendon of the peroneus longus. The synovial cavity of this joint is continuous with the plantar sheath of the tendon.

It is noticeable that at the insertion of the longus there is a pad of fat invaginated into the sheath on the deep aspect. It is comparable to an Haversian gland. The plantar sheath may have a complete meso-tendon. Sometimes the portion of this in relation to the fourth tarso-metatarsal joint is absent. The plantar sheath has been described as communicating occasionally with the tarso-metatarsal joints, but we have not observed such an arrangement. The presence of the meso-tendon seems to render a communication unlikely.

A bursa in relation to the peroneus longus is described below (fig. 3).

The Synovial Membranes in Relation to the Tendon of Tibialis Posticus. (Fig. 3.)

The main sheath of this tendon is 7 to 9 cms. long. It extends upwards to a point about 6 cms. above the internal malleolus; it is prolonged downwards to a point close to the scaphoid tuberosity, extending further on the deep than on the superficial aspect of the tendon. It sometimes happens that the sheath does not accompany the tendon as far as the point given

[1] Poirier, vol. ii., ch. iv., p. 302. [2] Spalteholz, vol. ii., p. 346.

above. In such cases there is a bursa between the tendon and the inferior calcaneo-scaphoid ligament. This arrangement we observed in a fœtus. The normal arrangement in the adult is for the sheath and bursa to com-

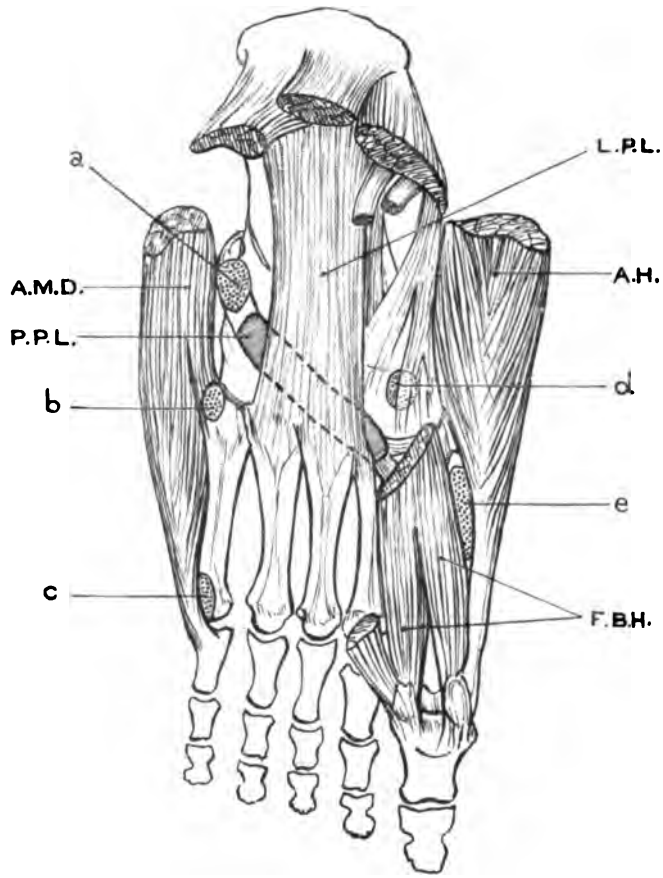


FIG. 3.—Diagram to show bursæ found in the sole of the foot.

a, *b*, *c*, bursæ in relation to the abductor minimi digiti; *d*, bursa in relation to insertion of tibialis posticus; *e*, bursa in relation to abductor hallucis; P.P.L., plantar sheath of peroneus longus; L.P.L., long plantar ligament; A.M.D., abductor minimi digito; A.H., abductor hallucis; F.B.H., flexor brevis hallucis.

municate. It is noticeable that there is no meso-tendon. Spalteholz[1] describes a bursa situated between the lateral tendinous process of insertion superficially and the scaphoid and internal cuneiform deeply (*d*, fig. 3). We have observed a bursa here. It is small, distinct from the main sheath,

[1] Spalteholz, vol. ii., p. 362.

and not always present. The same authority describes the sheath of the tibialis posticus as often communicating with that of the flexor longus digitorum, and, indirectly through this sheath, with that of the flexor longus hallucis. We have observed that on injecting the sheath of the tibialis posticus that of the flexor longus digitorum sometimes becomes injected also.

The Synovial Membranes in Relation to the Tendons of the Flexor Longus Digitorum and Flexor Brevis Digitorum.

In relation to these muscles we have to consider five sheaths. These are—one malleolar sheath for the tendon of the flexor longus digitorum, and four digital sheaths, one for each pair of long and short flexor tendons. These sheaths never communicate one with another. The malleolar sheath is 9 or 10 cms. long; it extends for 4·5 cms. above the tip of the internal malleolus; its highest point falls about 2 cms. short of that of the tibialis posticus sheath. On the deep aspect the sheath only reaches a point 3 cms. above the internal malleolus, for muscle fibres are passing to the tendon on the deep surface above this level. The sheath envelops the tendon under the internal annular ligament, and extends down as far as the point of crossing of the flexor longus hallucis and flexor longus digitorum tendons on the deep aspect; it falls 1 cm. short of this point on the superficial aspect. There is a meso-tendon throughout the length of the sheath. According to Spalteholz,[1] it sometimes communicates with the sheaths of the tibialis posticus and flexor longus hallucis tendons. We have observed both of these communications.

The Digital Sheaths. (Fig. 4.)

As the long and short flexors pass to the four outer toes, each pair is specially arranged in an osseo-fibrous tunnel. In this tunnel, opposite the first phalanx, the tendon of the flexor brevis digitorum bifurcates to allow that of the flexor longus digitorum to pass between its slips on its way to be inserted into the base of the ungual phalanx of the digit concerned. The fibres of the slips of the short tendon decussate after passage of the long tendon, but the two slips persist and are inserted into the sides of the second phalanx about its middle.

As the tendons lie in the osseo-fibrous canal they are enveloped in a synovial sheath, called a "theca," which extends from the level of the head of the metatarsal to the base of the ungual phalanx. Each theca is a blind tube of synovial membrane which entirely lines the osseo-fibrous

[1] Spalteholz, vol. ii., p. 361.

canal. At the extremity of the theca the synovial membrane is reflected on to each tendon, completely investing each one along its intrathecal course. The arrangement of this investment is complicated by the presence of the short tendon and of certain "vincula tendinum." In their intrathecal course the flexor tendons receive nerves and vessels, which pass to them in thin lamellæ or connective-tissue bands. The surfaces of these lamellæ are covered by synovial membrane. The lamellæ are, in fact, true meso-tendons; to them are applied the terms "vincula tendinum" or "ligamenta mucosa." They are subdivided into two sets—ligamenta longa and ligamenta brevia.

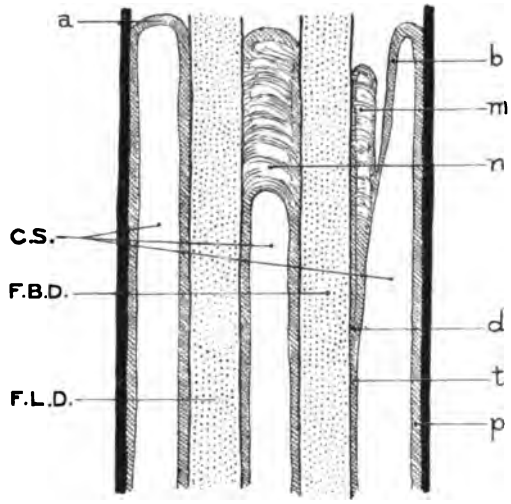


FIG. 4.—Diagram of longitudinal section taken at the proximal end of a "theca" in its middle line.

F.B.D., tendon of flexor brevis digitorum; F.L.D., tendon of flexor longus digitorum; *p*, parietal layer of synovial sheath; *t*, tendinous layer of synovial sheath; *m*, *n*, meso-membranes; C.S., cavity of synovial sac; *a*, *b*, *d*, see text.

In the foot we find two ligamenta brevia and at least two ligamenta longa. The former are triangular, with a free concave border; they occur one at the insertion of the long tendon and one at the insertion of the short tendon. The latter are more cord-like structures, stretching between the short and long tendons. At the level of the upper third of the first phalanx is sometimes found a quadrangular meso-tendon stretching from the bone to the tendon of the long flexor. Such a structure has been described[1] in the hand; we have observed it in two toes of a fœtus. In the adult the only trace of it which may persist is a ligamentum longum at this level; in cases

[1] Poirier, vol. ii., ch. iv., p. 120.

where this is present it is generally represented by two ligaments symmetrically placed.

The following is a detailed description of the relations of a pair of tendons and their digital sheath at different levels. These relations are the same in all the four digits concerned.

The sheath starts over the head of the metatarsal. The osseo-fibrous layer is reflected here to form the proximal cul-de-sac of the sheath. On the deep surface this reflection (*a*, fig. 4) forms the tendinous layer investing the long tendon (F.L.D., fig. 4). On the superficial surface we get a Σ-shaped arrangement as usual, but here this is somewhat modified. Poirier[1] compares this modification to a preputial sheath. The first reflection descends for about 1·5 cms. (*b*, fig. 4). Then it is folded back on itself. Having ascended for about 1 c.m. it is reflected on to the short tendon, forming its tendinous layer (*t*, fig. 4). Thus far the arangement is normal, and we have a small indentation at the proximal end of the digital sheath. (This indentation is represented by the middle two limbs of the Σ.) We find, however, that the indentation just referred to is drawn out into a point which is attached to the short tendon, on its superficial aspect, just as it begins to split (*d*, fig. 4). Poirier compares this attenuation to a frenulum.[1] Further, the sides of this now cone-shaped indentation are continuous with the osseo-fibrous layer laterally in the proximal half of their extent (*vide* figure in Poirier). In the middle line the cone-shaped sac is attached by a meso-structure to the tendinous layer of membrane covering the superficial aspect of the short tendon (*m*, fig. 4). The tendinous layers on the superficial aspect of the long tendon and on the deep aspect of the short one are continuous through a meso-membrane about 1·5 cms. long (*n*, fig. 4). Over the upper third of the first phalanx the tendon of the flexor brevis digitorum flattens and gradually splits; the flat slips so formed gradually diverge and pass towards the bones. Each slip is enveloped by a tube of synovial membrane. The tendon of the long flexor here shows signs of fission; it is prolonged straight on, enveloped in its synovial membrane. At this level there is no bond between the tendons or between the bone and tendons. Over the middle third of the first phalanx the slips of the short tendon have arranged themselves laterally to the long tendon. There is no connecting bond between the slips of the short tendon superficial to the tendon of the long flexor, but on the deep aspect of the latter a film of synovial membrane does connect them. Thus the long tendon lies in a groove formed by the slips of the short tendon and by synovial membrane. Passing from this connecting film of synovial membrane are two ligaments. One ligament is cord-like; it passes obliquely to the deep

[1] Poirier, vol. ii., ch. iv., p. 177.

surface of the tendon of the long flexor, being attached to the latter at a point more proximal than its point of origin from the connecting film. This ligament is a ligamentum longum. The other ligament is a ligamentum breve; as such it is triangular. By one border it is continuous right down to the insertion of the brevis slips, with the connecting film referred to above. By another border it is attached to the first and second phalanges and to the capsular ligament of the intervening joint for a length of 1·5 cms. from the insertion of the flexor brevis digitorum. Its base is free, and shows a concavity directed towards the heel. Over the lower part of the first phalanx the fibres of the two slips of the short flexor decussate. The latter are prolonged, to be inserted into the sides of the second phalanx about its middle. They are connected right down to their insertion by a film of synovial membrane. At the level of the proximal interphalangeal articulation a ligamentum longum stretches from the short tendons to the tendon of the long flexor. It is a firm but slight rounded cord, over 1 cm. long.

At the level of the lower end of the second phalanx the long tendon alone is in the sheath. It is inserted into the base of the ungual phalanx. A ligamentum breve stretches from it to the lower part of the second phalanx and the capsular ligament of the second interphalangeal joint. In one subject we saw the two ligamenta brevia in one sheet forming a complete meso-tendon from the head of the first phalanx to the base of the ungual one.

Many functions have been ascribed to the vincula tendinum.[1] That they act as check ligaments is not in accordance with their delicate structure. Henle, in remarking that the brevia contained yellow elastic fibres (vinculum subflavum), and that they adhered to the interphalangeal articular capsules, attributed to them the rôle of tensors of the synovial membrane of the joints (*cf.* subcrureus and subanconeus). This seems improbable, owing to the membrane of the joint being separated from the brevia by the capsules. Quain attributes to the yellow fibres the function of pulling down the tendons after flexion. This seems unnecessary, in view of the vaginal ligaments. Poirier sums up their function as that of conveyance and protection of the vessels and nerves to the tendons.

The Synovial Membranes in Relation to the Tendons of the Flexor Longus Hallucis.

This tendon has two sheaths. The upper lies in relation to the astragalus and os calcis, the lower to the digital osseo-fibrous canal. The

[1] Poirier, vol. ii., ch. iv., p. 121.

upper sheath extends to a point about 1 cm. above the ankle joint; it lies in relation here to the groove on the astragalus, there being a deep pouch between the tendon and the bone. Pads of fat are to some extent invaginated into this pouch. Below, the sheath ends about the level of the scapho-cuneiform joint, at or in front of the point of crossing of the flexor longus hallucis tendon and that of the flexor longus digitorum. It is 10 to 12 cms. long. According to Poirier,[1] it communicates in twenty per cent. of subjects with the sheath of the latter tendon at the point of crossing. There is no meso tendon. The digital sheath extends from a point near the base of the first metatarsal to the insertion of the tendon into the base of the ungual phalanx. It is longer than the other digital sheaths, and is not complicated by a short flexor tendon. The flexor brevis hallucis is inserted by two slips into both sides of the base of the first phalanx, a large sesamoid bone being developed in each slip. These bones glide over the tuberosities, and the two joints between the latter and the sesamoid bones are continuous with the joint between the phalanx and metatarsal. In the groove between the sesamoids lies the flexor longus hallucis tendon in its sheath. At the proximal end of the sheath we get a modification of the Σ-shaped arrangement similar to that found in the other digital sheaths. Superficially the arrangement is precisely the same, but on the deep aspect we find a meso-membrane between the tendon and the bone for about 1 cm.

In the fœtus and adult a strong quadrilateral meso-tendon is observed at the level of the first phalanx. At the insertion there is a somewhat vague ligamentum breve.

Communication between the digital and malleolar sheaths is exceedingly rare. In one case only has it been described.[2]

Further Serous Sacs in Relation to the Tendons of the Foot.

Bursa Subcutanea Tendinis Achillis is situated between the skin and the tendon near its insertion.

Bursa Tendinis Achillis is a large and constant bursa between the upper part of the posterior surface of the tubercalcanei and the tendon.

Bursæ of the Lumbricals.—These are small, and it is hard to decide whether they are bursæ or true sheaths. They are four serous sacs which more or less completely envelop the lumbrical tendons at their anterior ends. They are in close relation to the intermetatarso phalangeal bursæ. The three internal ones are the best marked and the most constant.[3]

[1] Poirier, vol. ii., ch. iv., p. 303.
[2] Chemin, *Soc. de Biol.*, 1896, p. 238.
[3] Macalister and Synnestvedt's Essay, p. 81.

Bursæ in relation to Abductor Minimi Digiti (fig. 3).—There are three described; we have seen them all.

(i) Synnestvedt[1] describes a bursa (*a*, fig. 3) between the muscle and the sesamoid bone in the peroneus longus tendon. He states he has not seen it elsewhere described. We can confirm its occurrence.

(ii) Part of the muscle forming the abductor ossis metatarsi quinti is inserted into the tuberosity of the fifth metatarsal. Between the tendon and the tuberosity is a bursa (*b*, fig. 3), for which on many bones a smooth facet may be seen. Synnestvedt[2] describes this bursa.

(iii) The same authority,[3] quoting Gruber, describes an occasional bursa (*c*, fig. 3) over the head of the fifth metatarsal, between the latter and the tendon of the abductor minimi digiti. We have seen a bursa here. It is continuous with the joint, and appears to us to be a protrusion of it.

Bursa in relation to the Abductor Hallucis.—The tendon of this muscle is inserted partly into the base of the first phalanx and partly with the inner head of the flexor brevis hallucis into the inner sesamoid bone. The tendons sometimes are blended along their whole course, and sometimes are separate right up to the sesamoid bone. In the latter case a bursa (*e*, fig. 3) intervenes between them at the level of the proximal end of the metatarsal bone. We cannot find a description of this bursa elsewhere.

Bursæ in relation to the Interossei.—These are mentioned by Synnestvedt[4] as occasionally occurring. He refers to Gruber.

Mode of Preparation of Specimens.

Our permanent preparations of synovial sheaths were made by injecting them with a coloured gelatin. Any non-diffusible colouring agent may be used for mixing with the gelatin. The gelatinous mass must be quite firm at room temperatures, and must therefore be injected warm. To inject a sheath we reflected the skin and superficial fascia together, and cleaned the deep fascia, taking care not to pierce it in so doing. We then made a small incision into the sheath, choosing a point for this purpose where the fascia exerted a considerable pressure on the tendon; we found that the fascia at such places acted as a valve, keeping the injection in at both ends of the sheath. Into the aperture so formed we introduced the nozzle of a syringe full of warm injection fluid. The calibre of the nozzle used was about the size of a pinhead. Having gently forced the coloured fluid as far as it would go, we poured cold water over the specimen before removing the nozzle.

[1] Synnestvedt's Essay, p. 78. [2] *Ibid.*, p. 78. [3] *Ibid.*, p. 81. [4] *Ibid.*, p. 80.

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Our thanks are due to Professor Macalister for his kindness in referring us to several of the above works; also to Mr Clayton Greene for his kind advice and suggestions.

MULTIPLE ANOMALIES IN THE UPPER EXTREMITIES OF ONE CADAVER.

By AUGUSTUS GROTE POHLMAN, M.D., *Junior Professor of Anatomy, Indiana University.*

A CADAVER was dissected during the summer session at Indiana University which presented numerous unusual anomalies in the upper extremities. The variable normal is a rather uncertain quantity, and for this reason only the major anomalies will be noted briefly. All the variations to be mentioned belong to the normal class—*i.e.* may be explained by reversion or aberrant development from a granted normal anlage. This in contradistinction to variations which may not be elucidated on a phylogenetic and ontogenetic basis, and are properly confined to teratology. The anomalies are grouped under the headings—brachial plexus, arteries, and muscles.

BRACHIAL PLEXUS.

The communication to the ulnar nerve from the outer cord, found in either plexus presented, I hold to be normal, or at least in 80 per cent. of the cases. The fibres are probably derived for the most part from the VIII. C. Note also that the median nerve has a double outer head in the usual type

VARIATIONS IN RIGHT PLEXUS. (See Fig. 1.)

1. The rhomboid nerve has a common origin with the uppermost twig of the posterior thoracic from the V. C. The nerve splits into three parts: (*a*) passes through the M. levator anguli scapulæ, giving off a branch to that muscle; (*b*) passes between the M. levator anguli scapulæ and the M. serratus anticus; (*c*) pierces the upper portion of the M. serratus anticus. All these parts reunite before they are distributed to the rhomboid muscles.

2. The internal anterior thoracic nerve arises by two heads from the inner cord. The roots of origin embrace the axillary artery.

3. The lesser interior cutaneous nerve is double.

4. The phrenic nerve arises from the IV. C. only.

VARIATIONS IN THE LEFT PLEXUS. (See Fig. 2.)

1. The rhomboid nerve is given off in common with the twig to the posterior thoracic from the V. C. as on the right side.

2. The phrenic nerve gives a communication to and takes a branch from the V. C.

3. The VII. and VIII. C.'s unite into one cord. The actual communication was verified by careful separation of the nerve trunks.

4. The I. T. forms the inner cord.

5. The outer cord and posterior cord are made up of three trunks: one from the united V. and VI. C.'s, one from the VII. and one from the VIII.

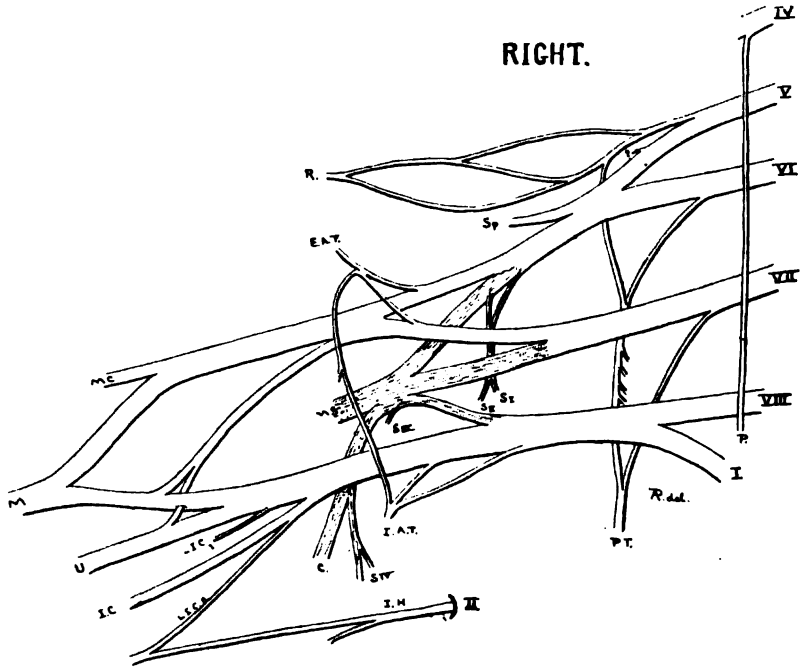


FIG. 1.

C.'s. The last-mentioned trunk to the outer cord is apparently carried over to the ulnar nerve through the uppermost outer median head.

6. The median nerve has three outer heads.

7. The exterior anterior thoracic nerve arises by three roots from the trunks that make up the outer cord.

8. The interior anterior thoracic nerve is replaced by a nerve arising by two heads from the trunks of the VII. and VIII. C.'s. The loop of communication embraces the anomalous superficial axillary vessel.

9. The inner cord sends two small branches to the musculo-spiral nerve.

10. The anterior branch of the lateral division of the III. T. enters the

plexus communicating with the intercosto-humeral from the II. T. (The nerve to the M. subclavius was lost on both sides.)

ARTERIES.

On the right, the axillary artery divides under the M. pectoralis minor into a superficial and a deep trunk. The superficial vessel is continued down

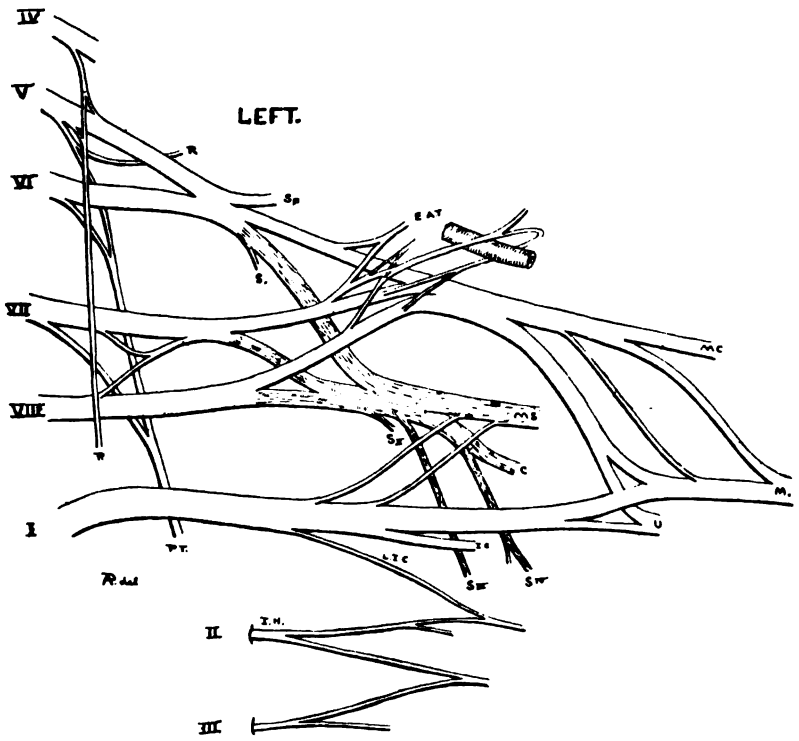


FIG. 2.

the arm as the brachial artery. The deeper artery gives off the subscapular, anterior and posterior circumflex, and the superior profunda. The superior profunda, in turn, gives off the inferior profunda, which has a normal course. This variation is, in a way, a transitional form between the normal and the anomaly on the left.

On the left, the axillary artery bifurcates at the lower border of the M. pectoralis minor. The superficial trunk gives off the long thoracic artery and the anastomotica magna. The deep trunk splits at the level of the joint into two divisions. The one passes down the arm as the second brachial

artery, giving off the superior and inferior profunda, and the other splits into the subscapular, anterior and posterior circumflex. (See fig. 3.)

Both brachial arteries are in close relation, and both are accompanied by veins. At the bend of the elbow the two vessels are reunited by a large loop anastomosis. The branches from the loop are muscular. The case is similar to the one reported by Miss Herrington in the Johns Hopkins

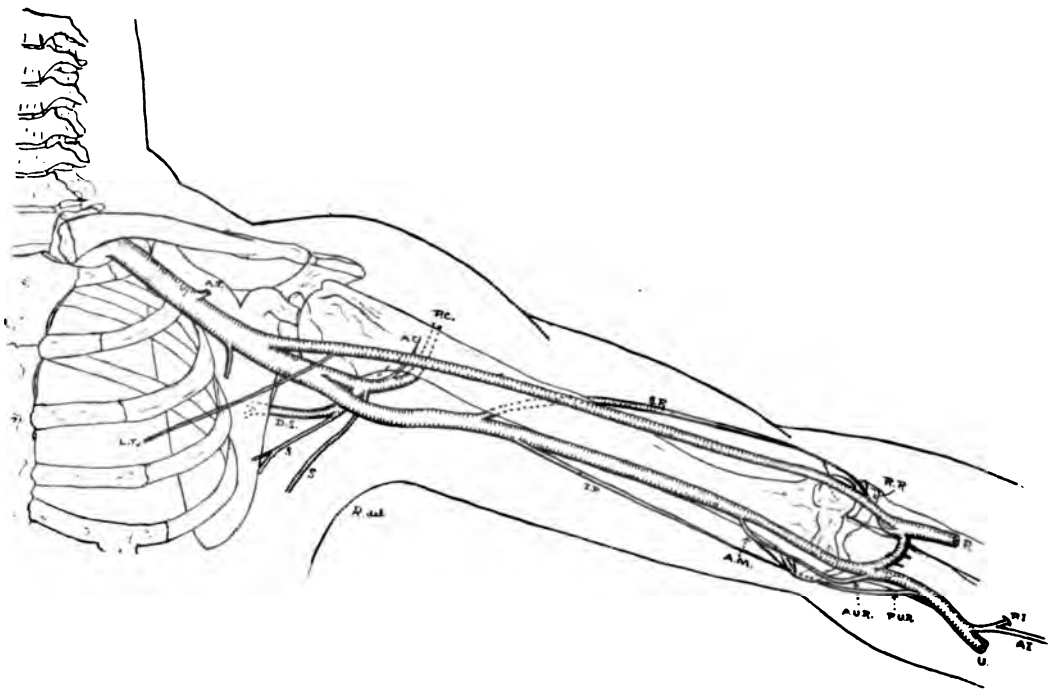


FIG. 3.

Bulletin for February 1905. The loop is called ramus anastomoticus (Henle).

MUSCLES.

1. M. epitrocleo-anconeus well developed on both sides. Origin from the mesial epicondyle and insertion into the olecranon. Nerve supply from the ulnar. The muscles bridge over the ulnar nerve and posterior ulnar recurrent artery.

2. M. biceps brachii. (See fig. 4.) Two heads normal. Origin of third head from the mesial surface of the humerus and from the intermuscular septum between M. brach. ant. and the M. triceps. The accessory head was

interposed between the brachial artery and the M. brachialis anticus, and was pierced by the median nerve.

The accessory head was inserted partly into the bicipital fascia, partly into the biceps tendon, but mostly into a large accessory tendon. The insertion of this tendon was remarkable. It was joined by a quadrilateral aponeurotic plate that replaced the upper portion of the deep head of the M. pronator radii teres, and the insertion was evidently into that muscle and into a common tendinous origin of the M. flexor carpi radialis and the M. flexor sublimis digitorum. The nerve was from the musculo-cutaneous.

3. M. pronator radii teres. The deep head arose from the accessory

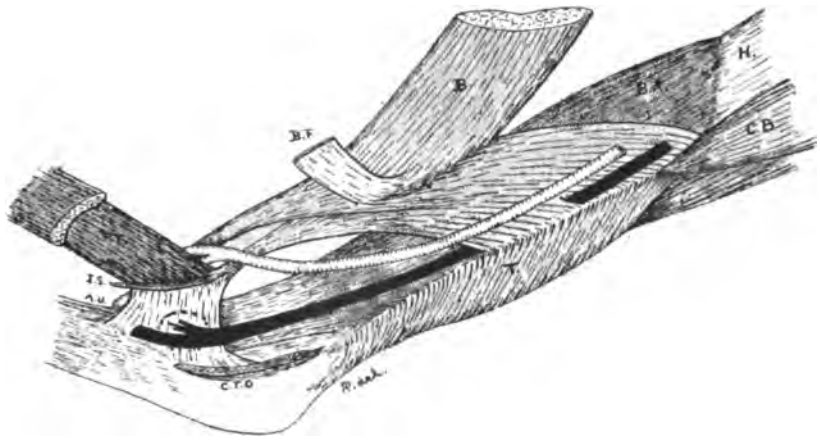


FIG. 4.

biceps tendon and from the quadrilateral fascial plate. The relations of the latter are identical with the upper part of the deep head of the pronator, which it seems to replace. A bursa was interposed between this plate and the M. brachialis anticus (dotted line).

Relations are shown in the sketch. The action of the accessory head of the biceps was undoubtedly strong flexion, but if any rotative influence was exerted on the forearm it was that of pronation.

4. M. abductor poll. brevis received an extra fleshy belly from the M. abductor poll. longus.

I wish to express my indebtedness to Mr James Scarborough for the care taken with the anomalies on the right, and to Mr Orin Dilley for the dissection of the parts on the left.

THE FASCIA OF THE PERINEUM AND PELVIS OF THE FEMALE, WITH SPECIAL REFERENCE TO THE MECHANICAL SUPPORTS OF THE PELVIC VISCERA.

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THE author lately published in this Journal a paper (1) dealing mainly with the fascia of the male pelvis, which contained merely a few general statements regarding the arrangement of this tissue in the female, as it was intended to devote a future communication to the consideration of the latter subject. The present paper may thus be regarded as a sequel to the previous one. The latter appeared in the *Journal of Anatomy* for October 1907; and it is an interesting coincidence that in the same number there should have appeared two papers by Derry (3) dealing with the same subject, and arriving at somewhat similar conclusions.[1] More recently Elliot Smith (18) has made a contribution to the anatomy of the pelvis, with which is incorporated a description of the pelvic fascia, supplementing Derry's work; while Fothergill (6) has published a paper dealing with recent advances in our knowledge of the anatomy of this fascia, in which he points out the important bearing these possess when considered from the clinical standpoint. The writer also quite lately made a communication (2) on the supports of the pelvic viscera, viewed in the light of recent researches on the anatomy of the muscles and fasciæ of the pelvic floor.

I. THE PARIETAL PELVIC FASCIA IN THE FEMALE.

It has previously been shown (1) that in the male pelvis the so-called parietal pelvic fascia really consists of the sheaths covering the pelvic surfaces of the obturator internus, pyriformis, and compressor urethræ

[1] Thus the "subperitoneal connective tissue," the importance of which is so strongly emphasised by Derry, closely corresponds to the "perivascular fascia" described by the author.

muscles. In the female the arrangement is practically the same, the only real difference being that the pelvic sheath of the last-named muscle will be found to become continuous with the connective-tissue capsule of the bladder instead of the prostate at the point where it is perforated by the urethra. Otherwise the muscle sheath blends extensively with that of the levator ani, as already shown in the male pelvis (fig. 1).

II. The Triangular Ligament of the Urethra contrasted in the Sexes.

The perineal sheath of the compressor urethræ in the male, as shown by Keith (10) and the author (1), is represented by the triangular ligament.

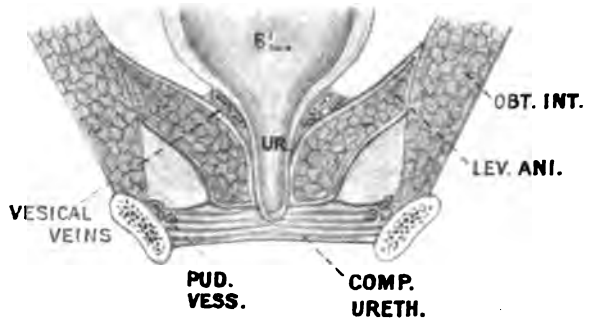


Fig. 1.—The relation of the levator ani to the female bladder and urethra and also to the compressor urethræ. These muscles have been separated from one another to some extent.

A study of the latter structure in both sexes clearly indicates that it ought really to be regarded as composite in nature. Thus in the male the superficial perineal muscles, and particularly the transversus perinei and accelerator urinæ, cover over the superficial aspect of the triangular ligament, and, as a result, the sheaths on their deep surfaces are fused with it, and indeed form a considerable proportion of the basal part of the ligament. It may be noted here that the existence of the pointed projection backwards from the base is explained by the fact that it is really the sheath on the deep surface of the accelerator urinæ, continued backwards, of course, to the origin of that muscle in the central point of the perineum. Other agencies which still further strengthen the triangular ligament are the sheaths of the bulb and crura, and those of the pudic vessels and dorsal nerves. The sheaths of the last-named structures are firmly fused with

the obturator fascia and the pubic arch, constituting the *fascia lunata* described by Derry (3). Those portions of the sheaths that are adherent to the obturator fascia form the so-called Alcock's canal, as shown by Derry (3), so that obviously this canal is not produced by a splitting of the above fascia, as described in books. The fibres of the compressor urethræ arise partly from the sheaths of these vessels and nerves as they course along the pubic arch, and this explains why the latter structures are described as being contained between the layers of the triangular ligament (fig. 1). As an appendix to these remarks, the author would like to add that the length of the membranous part of the urethra as usually given in books is much too great. He has rarely found it exceeding one-third of an inch in length.

The above reference to the superficial perineal muscles in the male leads one to refer also to the fascia on their superficial aspect. This will be found to form one common sheath for all these muscles, and to be, in fact, none other than the fascia of Colles. Since these muscles have a common sheath, this arrangement is rather suggestive of the fact that they constitute one continuous muscular stratum, and this is certainly the appearance presented by them when first exposed: they seem to be spread over the whole surface of the triangular ligament, and have therefore to be pushed aside in order to expose it. The so-called perineal triangle has in most cases no existence whatever, even as a potential space. The development of these muscles bears out this statement; for, as Thompson (22) shows, they are derived from the primitive sphincter cloacæ. They can be readily demonstrated as a *continuous layer* in the internal genital fold of a male fœtus at the beginning of the fourth month, and are therefore all developed in this fold.

The attachments of the fascia of Colles support this view of its morphology. Thus *externally* it invests the erector penis, and is therefore, like that muscle, attached along the pubic arch. *Posteriorly* it invests the transversus perinei and accelerator urinæ, and becomes continuous with the sheaths covering the deep surfaces of these muscles, and, through them, with the triangular ligament. This arrangement explains the attachment of the fascia of Colles to the base of the ligament. *In the middle line* it blends with the mesial raphe of the accelerator urinæ, which, it may be noted, represents the line of fusion of the muscular structures developed in the internal genital folds. *Anteriorly* the fascia becomes continuous with the epimysium of the dartos muscle. This is to be expected, since the latter is on the same morphological plane as the superficial perineal muscles, being, like them, developed round the embryonic urogenital orifice in the *external* genital fold, as an examination of this fold in a fourth-month male fœtus will readily show. The clinical interest attached to these remarks is, that

an extravasation of urine just in front of the triangular ligament must be into the sheaths of the superficial perineal muscles.

It is important to recognise the composite nature of the triangular ligament in the male, because in the female it is much less composite in character, and indeed tends to become broken up into its main constituents. Let us study first that portion forming the perineal sheath of the compressor urethræ. This muscle is in two parts in the female, one in front and the

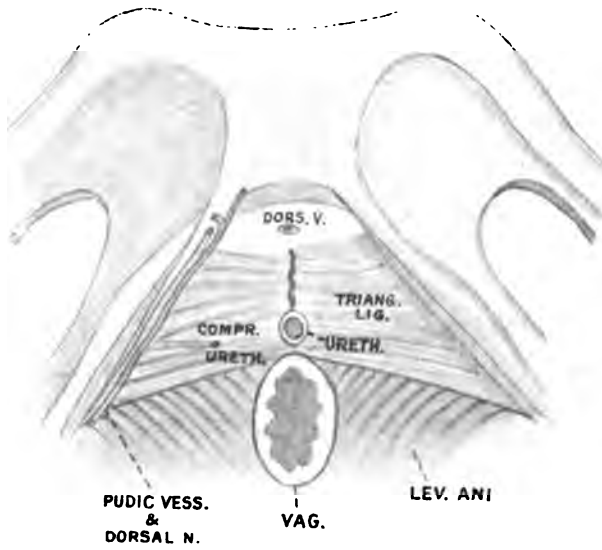


FIG. 2.—The relation of the triangular ligament to the compressor urethræ, and also to the urethra and vagina. Note that it passes entirely in front of the latter.

other behind the urethra, the latter portion being, in addition, embedded in the anterior vaginal wall (fig. 2). The triangular ligament follows a similar course, and fused to its superficial aspect are the sheaths of the bulb and crura clitoridis. The latter are especially intimate in their relationship, the effect being to prolong the attachment of the ligament backwards on each side along the pubic arch.

With regard to the basal portion of the ligament, it has been already shown that in the male it is formed, partly at least, by the sheath on the deep surface of the transversus perinei. On reflecting this muscle in the

female, one exposes a very scanty sheath, directed of course, like the muscle, behind the vagina, but connected in no way in front with the perineal sheath of the compressor urethræ by a continuous membrane. It is thus obvious that in the female the only portion of the "triangular ligament" which at all conforms to the description involved in this title is the structure constituting the perineal sheath of the compressor urethræ (fig. 2). This description does not accord with that of most text-books, where one finds it clearly stated that the vagina pierces the triangular ligament.

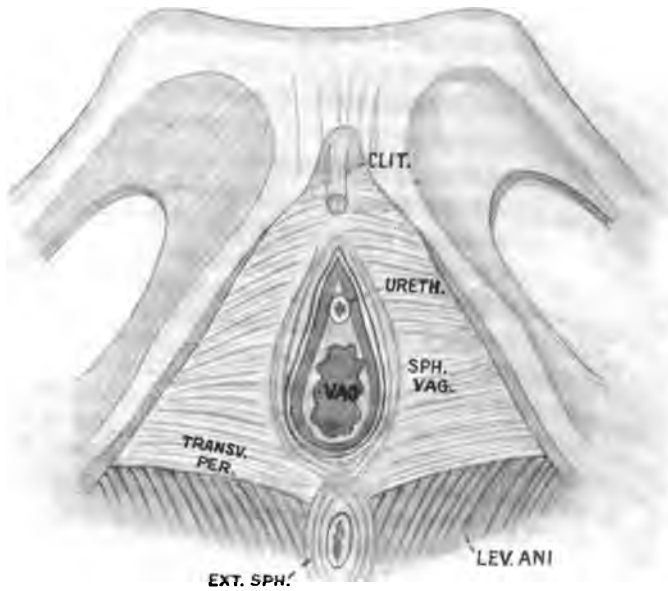


FIG. 3.—The usual condition of the superficial perineal muscles in an adult female.

Students seek in vain for such a structure, while the writer has always failed to demonstrate the existence of a membrane passing behind the vagina on a plane deeply to the bulb and crura clitoridis. One can, however, as a rule, readily expose a structure agreeing in every way with the accepted description, but passing *superficially* to the bulb and crura (fig. 3). The author has been able to demonstrate this structure in all the subjects dissected; but it ought to be mentioned that every one was over the age of forty, though in every case the pelvic outlet appeared otherwise normal, the perineum having been untorn. It is best shown by incising the skin and fasciæ along the line of the pubic arch, and then working the handle of the

knife transversely towards the middle line. The structure thus exposed is membranous in nature, and is firmly attached to the pubic arch superficial to the crus. Towards the vaginal orifice it becomes continuous with the sphincter vaginæ, and posteriorly with the sphincter ani externus. Under cover of its posterior margin will be found a few muscular fibres representing the transversus perinei. Apparently, then, in the female the muscular element of the primitive sphincter cloacæ does not attain to anything like the degree of development in the male. It is, in fact, mainly represented by the muscle sheath which forms the membranous structure above referred to. The latter, from its position, is obviously the fascia of Colles, which is therefore by no means the thin delicate structure it is believed to be in the female. Indeed, it would appear to be better developed in the female than in the male, contrary to the statements found in books.

III. The Visceral Pelvic Fascia in the Female.

What is usually known as the visceral pelvic fascia in the female may be divided into three groups:—

1. The fascia forming the sheaths of muscles.
2. The fascia forming the sheaths of vessels in relation to the pelvic viscera.
3. The fascia forming the sheaths of viscera.

(1) The only *muscle sheath* which is included in this category is that covering the pelvic surfaces of the levator ani and coccygei muscles, as already shown in the case of the male. This is often described in books as splitting into four layers—vesical, vesico-vaginal, recto-vaginal, and rectal. Note again that, just as in the male, no splitting really occurs, for the sheath forms one continuous fascial plane from before backwards.

These should therefore not be termed "layers," but simply *portions* of this sheath. The *vesical portion* follows those fibres of the levator ani which pass by the lateral aspect of the bladder, and blend with its connective-tissue capsule, as well as with the sheath of the vesical veins, which are very prominent at this point, just as in the male (figs. 1 and 4). The *vesico-vaginal portion* is very insignificant, and is in relation to those fibres of the levator ani which lie opposite the interval between the base of the bladder and the anterior vaginal wall. This is the lower limit of a connective-tissue inter-visceral partition that is completed higher up by the sheaths of the vessels lying between the bladder, uterus, and vagina. Opposite the vagina the sheath is carried down on its lateral wall along with the fibres of the levator ani. The *recto-vaginal portion* is the pelvic sheath for those fibres of the levator ani that are inserted into the central

point of the perineum. This, like the vesico-vaginal portion, is continuous above with the sheaths of the vessels passing between the vagina and rectum. The *rectal portion* is carried down with the fibres of the levator ani on the lateral walls of the anal canal, whilst behind this it passes

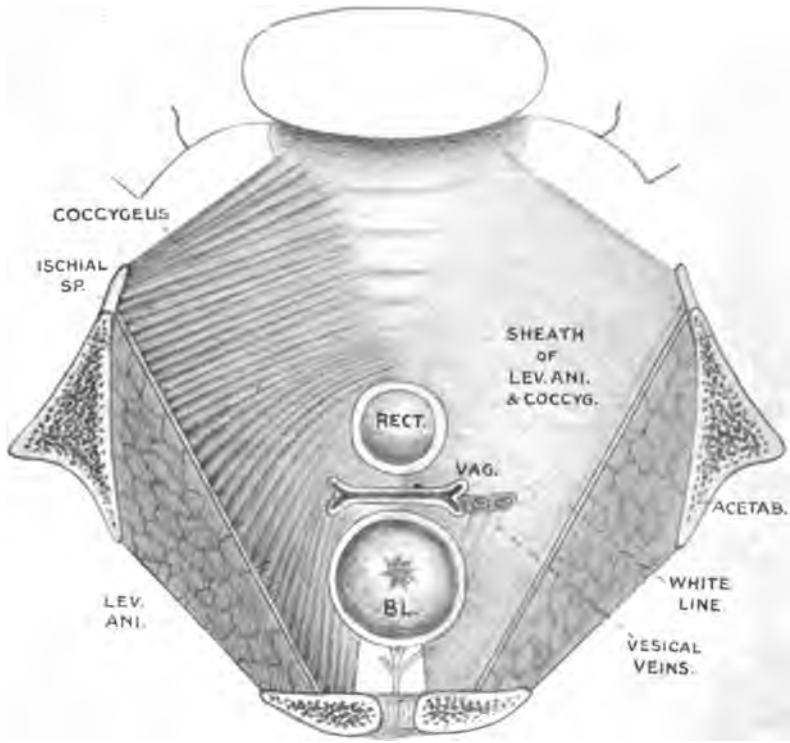


FIG. 4.—Female pelvis. The levator ani and coccygeus are exposed on the right side. On the left is shown their fascial sheath.

inwards, along with the fibres of the levator ani and coccygeus, to the mesial plane. and also to the sides of the coccyx (fig. 4).

The anterior true ligaments of the bladder are here, as in the male, formed by the union of the pelvic and perineal sheaths of the levator ani round its free anterior margin. The muscle sheaths of opposite sides are united by a layer of areolar tissue surrounding the plexus, into which the dorsal vein of the clitoris breaks up at this point (fig. 4).

Posteriorly the pelvic sheath of the levator ani and coccygeus sweeps round the free margin of the latter muscle and blends with the small sacro-sciatic ligament, *i.e.* the sheath on the superficial aspect of the same muscle.

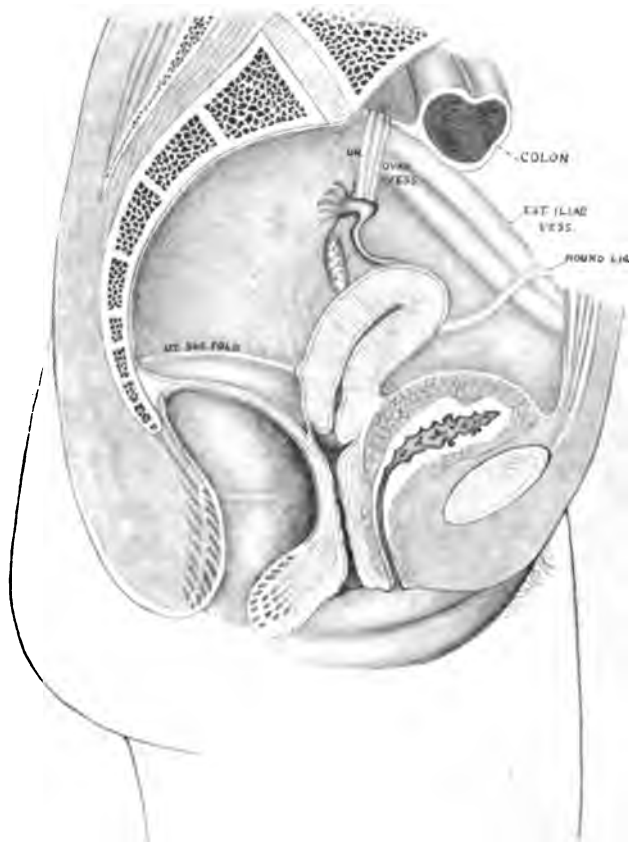


FIG. 5.—Mesial section of a female pelvis, showing the relation of some of the visceral branches of the internal iliac vessels to the side wall of the pelvis.

(2) *The fascia forming the sheaths of vessels.*—This mass, which the author has previously termed the perivascular fascia, will be found to have an arrangement very similar to that in the male. It is the attachment of this fascia to the upper surface of the pelvic sheath of the levator ani and coccygeus that has given rise to the erroneous descriptions regarding the

splitting up of the latter sheath into layers, as frequently described in text-books. Thus the perivascular tissue carried in between the bladder and vagina constitutes the "vesico-vaginal layer," while that between the rectum and vagina represents the "recto-vaginal layer" of the "visceral pelvic fascia." The intervals between these viscera are full of blood-vessels surrounded by their sheaths (fig. 5). A fuller description of this tissue will be furnished later when dealing with its function as a supporting agent to the pelvic viscera.

(3) *The fascia forming the sheaths of the viscera.*—The author, in his previous paper (1), has termed these the connective-tissue capsules of the viscera, and has pointed out that they are not derived from an extension on to the viscera of the "visceral pelvic fascia," as has been formerly described in text-books. Keith (10), Paterson (16), Derry (3), and Elliot Smith (18) have also directed attention to the fact that the pelvic viscera, like those elsewhere, possess their own special sheaths. When one considers that the chief viscera of the pelvis, *e.g.* the rectum, bladder, and uterus, are muscular organs, it is obvious that they must possess their epimysium like similar tissue elsewhere.

IV. The Mechanical Supports of the Female Pelvic Viscera.

In all the well-known gynæcological text-books "the pelvic floor" is usually given as the supporting agent of the contained viscera. It is therefore convenient to give here Thompson's definition (22) of this floor:[1] —"the pelvic floor is a thick compact mass, traversed by 'clefts' or 'faults,' the walls of which are normally in contact, but which open up for the passage of material through them. It includes the whole of the soft structures that close the outlet of the pelvis." The anatomy of the female pelvic floor has claimed attention from many writers, amongst whom may be mentioned Dickinson (4), Fothergill (6), Doran (5), Goffe (7), Berry Hart (8), and Symington (19). Gynæcologists single out the muscles of the pelvic diaphragm, namely, the levator ani and coccygeus, as constituting the essential supporting agent in this floor. A considerable number of investigators, such as Thompson (22), Holl (9), Kollmann (11), Lartschneider (13), and Paulet (17), have studied the morphology and comparative anatomy of these muscles, and have pointed out that they are really to be regarded as rudimentary structures in man, since they respectively represent the flexors and abductors of the tail in lower animals. In this relation it is significant to note Thompson's remarks (22) with reference to these muscles. He says:[2] "As regards the pelvic diaphragm, it is interesting to find that

[1] *Op. cit.*, p. 139.

[2] *Op. cit.*, p. 140.

although it contributes to the support of viscera, the muscles which constitute it, viz. the levatores ani and coccygei muscles, are derived from the flexors and abductors of the caudal end of the vertebral column. In tailed mammals this group of muscles passes from the side wall of the pelvis to the tail, and move that structure. But, coincident with the assumption of the upright posture, not only is the number of caudal vertebræ reduced, but the muscles which move them undergo similar retrogressive changes. This group is now available for other functions and it eventually undergoes such modifications as to form the diaphragm, which is such an essential feature of the pelvic floor in some of the primates." It is also important to quote Bland-Sutton's views on this subject. He states, on p. 3 of his book (23): "When a muscle degenerates, either from morphological or pathological causes, the amount of contractile tissue is diminished, and the parts take on the character of fibrous tissue and become ligament. This change may conveniently be referred to as regression." Again, on p 76 he remarks: "It seems clear that the stout and complicated pelvic fascia of man arises from the regression of the levator ani group of muscles due to the suppression of the caudal vertebræ." These observations are most suggestive, seeing that the pelvic sheath of the levator ani and coccygeus is distinctly aponeurotic in character as a rule, and may therefore quite possibly represent a transformation of the contractile element into fibrous tissue. It is thus obvious that if we are to regard these muscles as retrogressive in evolution, then we cannot allocate to the contractile tissue itself the chief part in supporting the viscera. That they have really undergone retrograde changes is at once proved by dissecting them out. In most cases they will be found to be exceedingly thin, though one occasionally meets with instances where they still show robust development. It is of interest to mention here that Dr Arnold Lea (14) has devised exercises for developing and strengthening these muscles, as a means of increasing their efficiency as a pelvic support.

It is apparent, however, that we must look for other visceral supports besides the muscles of the pelvic floor. These will be found to be furnished by the pelvic fascia just described, and particularly that part forming the pelvic sheaths of the levator ani and coccygei muscles, and that enveloping the blood-vessels—*the perivascular fascia.* That portion of the latter tissue in association with the uterus is synonymous with *the parametrium.* A study of the relation of the pelvic diaphragm to the viscera, and more particularly to the uterus and vagina, will make this point more apparent. One must remember that the levatores ani muscles are attached to the lower part only of the vaginal wall. True that the muscles pass downwards for some considerable distance on the wall before becoming actually inserted into it (fig. 6); but still one must recollect that above the level of the com-

paratively thin-walled vagina is the uterus, which has therefore no direct support whatever from the above muscles. The levatores ani from both sides form a funnel-like arrangement, as Fothergill (6) and the author (2) have already pointed out; and it is clear that if the only support of these viscera were from below, then the weight of the uterus and superincumbent intestines would force the thin-walled vagina, concertina-like, down to the bottom of the funnel. Then why do these viscera not normally tend to sink downwards thus? The answer is that they are bound firmly to the

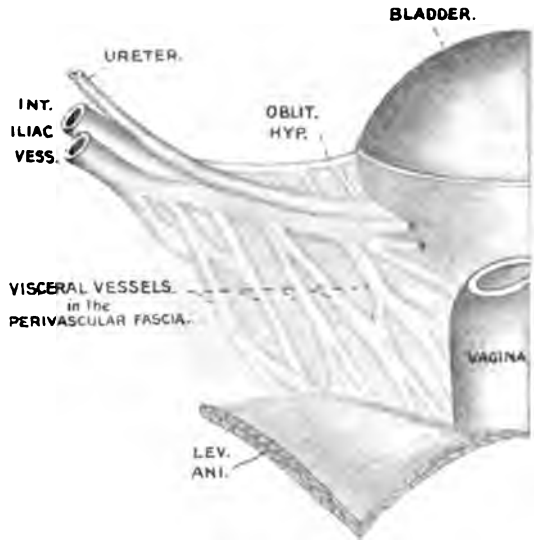


FIG. 6.—Viscera of female pelvis, showing the relation of the base of the bladder to the visceral vessels and perivascular fascia.

sides of the funnel by the perivascular fascia surrounding the blood-vessels passing to these viscera (fig. 7). The presence of the latter tissue is best demonstrated by making a sagittal section through the pelvis just clear of the viscera, when it will be found to constitute a compact mass filling up the interval between the peritoneum and the pelvic sheath of the levator ani and coccygeus which furnish its upper and lower attachments. A glance at fig. 8 shows that this mass is full of blood-vessels, while it also contains a rich plexus of sympathetic nerves, with their dense sheaths (including the pelvic plexuses), and the ureter. All these structures are bound together by the dense perivascular fascia which completes the composite

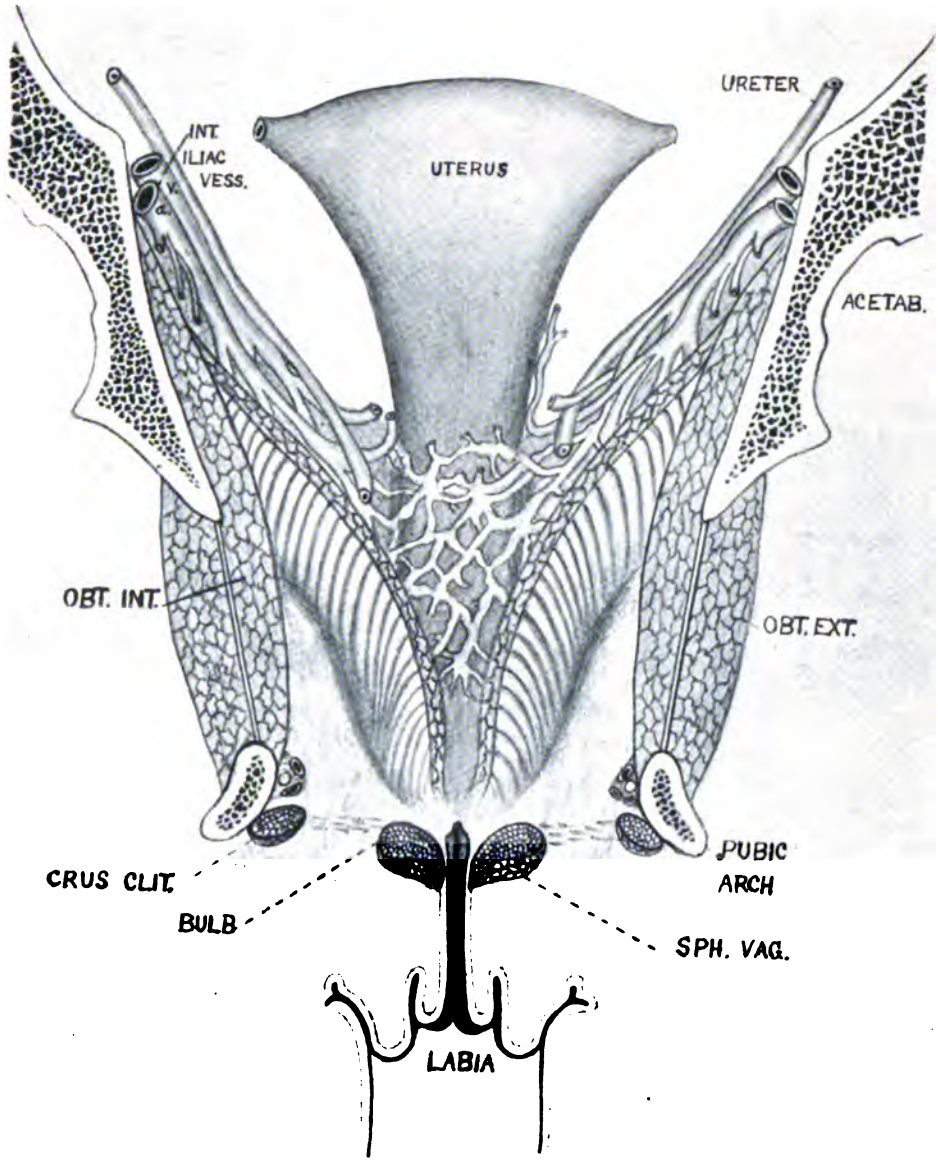


FIG. 7.—Oblique section of a female pelvis, of which the upper part is in a plane much posterior to the lower part. It shows the funnel-like arrangement of the levator ani muscles. The blood-vessels, and especially the veins, are injected.

mass (fig. 8). The latter is thin anteriorly, but gradually increases in thickness as it is traced backwards, and this will be found to be greatest opposite the broad ligament and utero-sacral fold of peritoneum (fig. 8). This figure also clearly demonstrates the fact that the tissue is subserous in nature, as pointed out by Derry (3). The importance of the perivascular fascia is probably best appreciated by making a section of the pelvis such as that

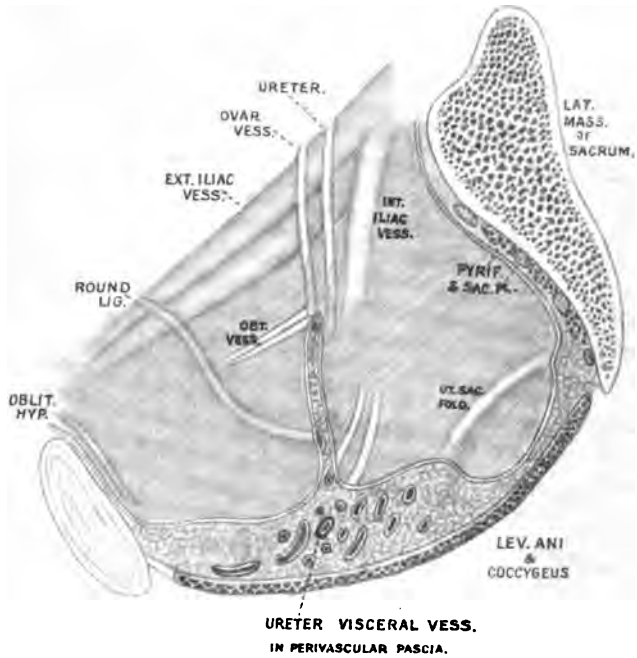


FIG. 8.—Sagittal section of a female pelvis just to the right of the viscera. The relation of the perivascular tissue to the levator ani and coccygeus is well shown.

represented in fig. 8. Its attachments are as follows:—above to the peritoneum, below to the pelvic sheaths of the levator ani and coccygeus, externally to the obturator fascia, and higher up to the periosteum of the innominate bone, while internally it blends with the connective-tissue capsules of the viscera. Its attachment to the lateral pelvic wall is rendered further secure by the fact that the parietal branches of the internal iliac vessels pierce the pelvic parietes in order to reach their respective destinations, and in doing so their sheaths blend with the surrounding bony and

muscular structures. The effect is to firmly anchor the visceral branches of the same vessels and their sheaths firmly in position. Further, it will be found that the main trunks of the internal iliac vessels, in their descent on the lateral wall of the pelvis, are bound down to the latter by dense areolar

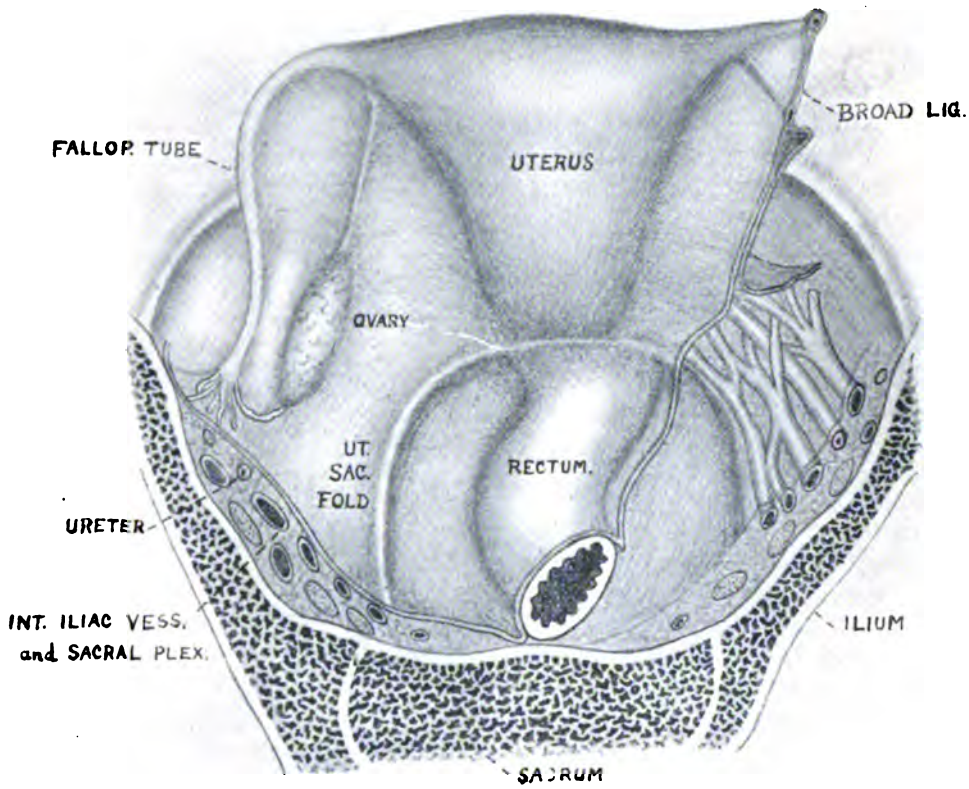


Fig. 9.—Oblique section of the sacrum and ilia, designed to show the relation of the vessels and perivascular fascia to the utero-sacral folds.

tissue. The suspensory ligament of Paterson (16), the ligamenta cardinalia of Kocks (12), and the transverse ligament of Mackenrodt (15) may be recognised as the perivascular tissue *plus* the pelvic sheath of the levator ani and coccygeus, to which it is attached below.

It is convenient to refer also at this point to the relation which the

perivascular fascia bears to the utero-sacral ligaments. A study of fig. 9 will show that these structures are not specially developed bands, but are simply part and parcel of the general perivascular mass. The latter fills the whole of the sides of the funnel referred to above, and its posterior part blends with the sheaths of the sacral plexus and the pyriformis, and through these with the sacrum. This tissue, in sweeping forwards from the sacrum to the uterus, constitutes the lateral boundary of the rectal channel of Paterson, and possesses an upper rounded margin, over which the peritoneum is moulded to form the utero-sacral fold. The tissue immediately underneath the latter contains a considerable amount of non-striped muscle, but nevertheless this does not detract much from the fact that it is perivascular in nature.

There is a prolongation of the fascia behind the rectum in the form of a dense areolar tissue which binds the bowel firmly to the sacrum, coccyx, and the sheaths of the sacral nerves. Mr J. W. Smith informs the writer that he has been very much impressed with the density of this fascia; for he finds that in performing Kraske's operation he has usually to have recourse to the knife to cut through it, as it offers great resistance to the passage of the finger in separating the bowel from the sacrum and coccyx.

The remaining structures which may be considered as supports of the pelvic viscera are the peritoneum, the round ligaments, and the obliterated hypogastric arteries. The peritoneum may be regarded as a support, in the sense that it furnishes the superior attachment of the perivascular fascia, and thus renders the composite nature of the latter more manifest. The utero-sacral fold of the peritoneum, as such, cannot be seriously regarded as of much supporting influence to the uterus, while the broad ligaments are usually in so relaxed a condition that their function as an agent of support must be practically *nil*. Note that the tissue between the layers of these ligaments is continuous with the perivascular fascia (fig. 10). With reference to the round ligaments, it ought to be noted that they are essentially embryonic in function, as Fothergill (6) has pointed out. They are the homologues of the gubernacula of the testes in the male, and their duty is to drag down the ovaries, tubes, and their appendages from their embryonic site on the dorsal wall of the abdomen to their permanent or adult position within the pelvis. Even a cursory examination of these ligaments will at once establish the fact that they are usually in a relaxed condition, and, as such, can have little or no supporting action on the uterus (fig. 5).

It is different, however, with the obliterated hypogastric arteries. They must obviously possess some influence as a pelvic support, seeing that they are a direct continuation of the internal iliac arteries (fig. 11). On dissecting them out, it will be found that their sheaths are intimately blended with the perivascular fascia. They form two slings, which pass forward on each

side in close relationship to the pelvic viscera, particularly the bladder. This sling-like arrangement is especially noticeable in the fœtus, in which, of course, they are relatively large and prominent (fig. 11).

The author regards the perivascular fascia, *plus* the pelvic sheaths of the levator ani and coccygei muscles, as the most important support of the pelvic viscera in both the male and female. In considering this function of the fascia it is probably most satisfactory to look upon the whole of the perivascular tissue on both sides of the pelvis as one composite mass. Indeed, its efficiency as a visceral support entirely depends upon its pre-

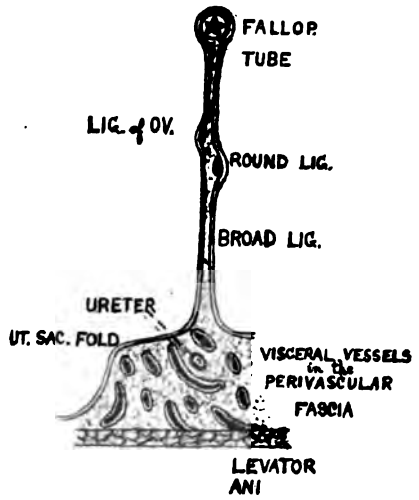


FIG. 10.—Relation of the perivascular tissue to the levator ani, and also to the broad ligament

serving its composite condition. Therefore any abnormal influence which tends to remove or alter in any way this compact arrangement, such as blood extravasations or inflammatory and other processes, will most certainly impair also its supporting powers.

The results of the present investigation clearly indicate that in prolapse of the female pelvic viscera the fault is not only at the outlet but also higher up in the pelvis, owing apparently to a relaxed condition of the perivascular fascia and the pelvic sheaths of the levatores ani and coccygei. Thus Fothergill (6) points out that there is frequently no tendency to prolapsus uteri even after long-standing laceration of the perineum; and he explains this as due to the perivascular fascia retaining its tone and, with that,

its efficiency as a visceral support. It is therefore clear that operative measures for the severer types of this condition must be directed not only to the pelvic outlet, but also higher up. The author, in conclusion, would suggest that an operation which has for its object the restoration of the composite condition of the fascia—the drawing in of the slack, as it were—will probably be the one that is found most successful in dealing with the more extensive forms of prolapse of the female pelvic viscera, which, it must

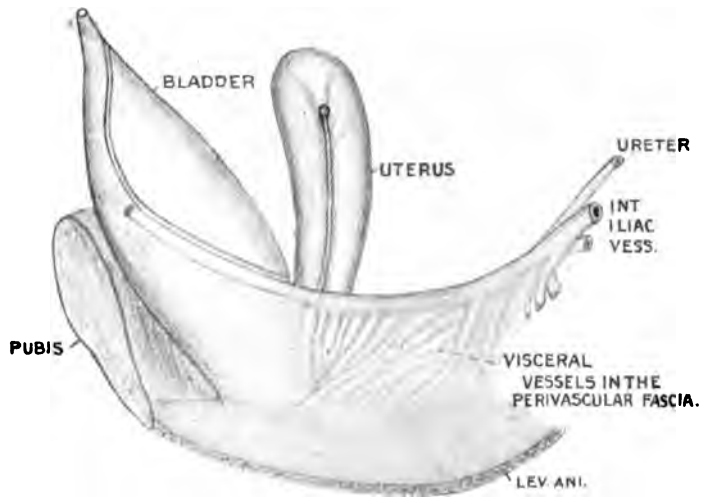


FIG. 11.—Pelvic viscera of female fœtus at full term. Enlarged. Note the relation of the hypogastric artery to the internal iliac.

be admitted, so frequently defy all attempts at treatment by the methods at present at our disposal.

This research was conducted in the Anatomy Department of the University of Manchester, and the descriptions are founded on dissections of specimens preserved in the ordinary way, and also others which were injected with formalin. The author wishes to thank Professor Young for a liberal use of material, as also for numerous other facilities granted during the progress of the work. This research was begun under the terms of tenure of a Carnegie Fellowship, and the author desires further to express his indebtedness to the Executive Committee of the Carnegie Trust for a special grant of money to cover the cost of the illustrations.

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ANATOMICAL NOTES.

Meckel's Diverticulum in Mammalia. By W. McAdam Eccles, M.S.

I have been unable to find any specimen of a true diverticulum of Meckel in any of the mammals lower than man. They have been described in the ape, the dog, and the lamb, but I do not know of the existence of one in London. Care has to be taken not to confuse the acquired, pathological diverticula, which may occur at any point in the length of the intestine and may be multiple, with a true diverticulum as described by Meckel, which has a developmental origin, and is always at or near the same part of the small intestine, namely, not far from the ileo-cæcal junction.

But, seeing that this diverticulum is by no means unimportant in man from a practical and surgical point of view, I should like to draw attention to some debatable conditions relating to it. Most of the specimens which have permanent attention drawn to them find their way into our museums, because they have caused death by inducing intestinal obstruction. In some of these there will be found a fine cord running from near the apex, if not from the actual apex, of the diverticulum to the umbilicus. In others there is a similar cord passing from the ventral aspect of the mesentery, with or without a Meckel's diverticulum being present, and being attached at its other end either to the umbilical region or to some organ, or having this end free, that is, quite unattached. It has been stated that as many as three of these cords may be present in the same individual, all existing close to one another. They consist, as a rule, of fibrous tissue, and are generally impervious. Their origin is a matter of interest. Bearing upon this is the question of the vessels supplying the diverticulum, and those which are associated with it. The arteries in connection with the diverticulum are derived from three possible sources, namely, from those of that part of the ileum from which the diverticulum springs, from vessels of the abdominal wall to which the distal part of the diverticulum is attached, or from those in abnormal adhesions which the diverticulum has acquired. Any one of these vessels may be the origin of these peculiar and dangerous cords which not infrequently cause intestinal obstruction in the human subject.

Another matter of considerable interest, and still very obscure, is the method by which a Meckel's diverticulum becomes partially or completely

obliterated, and what is the reason why in some instances it remains as a patent tube in its whole length.

A very large number of pathological conditions may be associated with the diverticulum in addition to strangulation. Inflammation, cysts, calculi, prolapse, fistulæ, intussusception, and hernia have all been existent and dependent upon the diverticulum. Its presence is certainly a menace to life, and a closer study of its formation, obliteration, and the several conditions associated with it, would well repay the labour spent.

Persistence of the Vessels of the Yolk Sac. By Arthur Keith, M.D., *Conservator of Museum, Royal College of Surgeons, England.*

In an exhaustive article on Intestinal Obstruction, contributed to Clifford Allbutt's *System of Medicine* (vol. iii. p. 772, 2nd ed. 1907), Mr Barnard divides the various cords which are found in connection with a Meckel's diverticulum, and are apt to cause acute obstruction, into four classes: (1) Cords stretching from the apex of the diverticulum to the umbilicus, formed by atrophy of the vitello-intestinal duct; (2) cords from the apex f the diverticulum ending in an adjacent part of the mesentery; (3) cords running from the mesentery to the umbilicus, vestiges of the artery of the yolk sac; (4) bands formed by the extension of inflammatory adhesions of the diverticulum.

Dr Chalmers Mitchell found no trace of a Meckel's diverticulum in a series of dissections of the intestinal tract which included over two hundred mammals (*Trans. Zoo. Soc.*, vol. xviii. p. 438, 1905), but found that it occurred constantly in certain groups of birds (*Trans. Linnean Soc. Lond.*, vol. viii. p. 173, 1901). In birds the diverticulum is frequently furnished with a mesentery, an extension from the mesentery of the ileum, and occasionally a strong band runs from this mesentery towards the liver.

While examining the hearts of three newly born polydactylous kittens, born of a polydactylous mother, I found in one of them two attenuated fibrous cords passing from the umbilicus and ending amongst the intestines (see fig. A). One of them terminated in the mesentery of the duodenal loop and joined there the portal vein, while the other ended in the mesentery of a loop formed by the distal part of the ileum, in the neighbourhood of a superior mesenteric artery. One cord was clearly a remnant of the artery of the yolk sac, the other cord—that which ended in the portal vein—a remnant of the vein of the yolk sac. In the second kitten there was merely the arterial cord, while in the third kitten neither of these cords was present. There was no trace of a Meckel's diverticulum

in any one of the three. The cord mentioned by Dr Mitchell as occurring occasionally at the site of the mesentery of a Meckel's diverticulum in birds is evidently a proximal part of the vein of the yolk sac.

Some five years ago, in a male subject in the dissecting-room of the London Hospital, a cord was observed to pass from the mesentery of the ileum, near the usual site of a Meckel's diverticulum, and end at the umbilicus (fig. B), and such cords have been several times observed by surgeons. They are apparently vestiges of the artery of the yolk sac. It is possible that the cords seen running from the apex of Meckel's diverticulum to the umbilicus are also remnants of the artery and not vestiges of the vitello-intestinal duct, but of this I have no microscopic proof.

The form of cord shown in fig. C is difficult to explain: it runs from near the apex of a diverticulum to the mesentery of the bowel, near to, or

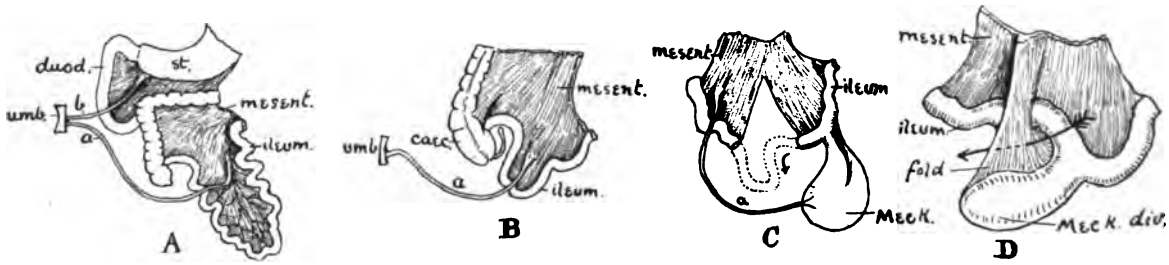


FIG. A.—Diagram of the viscera of a kitten showing a cord passing from the umbilicus to the mesentery of the ileum (*a*), and another to the mesentery of the duodenum (*b*).

FIG. B.—Specimen (No. 1334A, London Hospital College Museum) showing a cord passing from umbilicus to mesentery of ileum, from a dissecting-room subject.

FIG. C.—Specimen (No. 1336, London Hospital Medical College Museum) showing cord passing from apex of Meckel's diverticulum to mesentery.

FIG. D.—Specimen (No. 1337A, London Hospital Medical College Museum) showing mesentery to a Meckel's diverticulum which caused constriction of bowel.

occasionally at some distance from, the diverticulum (fig. C). This form of band is a very common cause of obstruction (see the data collected by Mr Barnard), and it too is apparently a remnant of the *proximal* part of the artery of the yolk sac. The key to their formation seems to be given by the specimen illustrated in fig. D. In that specimen the diverticulum is provided with a mesentery of the same form as is described by Mr Mitchell in birds. In the free edge of the diverticular mesentery is a fibrous cord. Now, if the attached part of the diverticular mesentery were to disappear—the part perforated by the arrow in fig. D, and this is the thinnest part of the mesentery—then a cord would be left in the position of that shown in fig. C. In the development, growth, and elongation of the bowel such a disappearance of the attached part of the cord is very likely to occur. The cord left after disappearance of the mesentery is often so

short as to actually constrict the part of bowel it crosses when passing from the diverticulum to the mesentery.

Hammer-shaped Meckel's Diverticulum. By Reginald J. Gladstone, M.D.

A hammer-shaped Meckel's diverticulum in the museum of the Middlesex Hospital has been described by Mr Leopold Hudson. This specimen shows on one side a small fold of mesentery containing both pervious and obliterated vessels. The vessels he believed to be omphalo-mesenteric in their origin, and the fold of peritoneum forming the mesentery to be raised by the tension of the vessels.

In the same museum there is another specimen with a Meckel's diverticulum 4½ inches in length.

Multiple Spleens. By F. G. Parsons, F.R.C.S.

A specimen of multiple spleens was recently taken from a girl æt. 13 in the P.M. room of St Thomas's Hospital.

The main spleen was 4½ inches long by 2 inches broad, and occupied the usual position. Situated below the greater curvature of the stomach, and between the anterior two layers of the great omentum, were three other spleens of which the largest was 3 inches by 2 inches, while the two smaller were globular masses of about 1 inch in diameter.

The interest of the specimen consisted in the fact that the main spleen was quite the usual size for a child of this age. Nothing abnormal was noticed in the lymphoid tissue elsewhere in the body.

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